ROLE OF ULTRASOUND IN THE DIAGNOSIS OF CARPAL TUNNEL SYNDROME

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Dedicated

to

my family

&

Teachers

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ABBREVIATIONS

BMI-	Body Mass Index
CMAP -	Compound muscle action potential
CSA -	Cross sectional area
CTS -	Carpal Tunnel Syndrome
DML -	Distal motor latency
EDT-	Electrodiagnostic tests
IOR-	Inlet to outlet median nerve area ratio
LR -	Likelihood ratio
MRI -	Magnetic resonance imaging
NCS -	Nerve Conduction Study
NCV -	Nerve conduction velocity
NPV -	Negative Predictive Value
PPV -	Positive Predictive Value
ROC-	Receiver Operator curve
SD-	Standard deviation
SNAP -	Sensory nerve action potential
USG –	Ultrasonography

ABSTRACT

Introduction: Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy of upper limb owing to compression of median nerve currently diagnosed by combination of clinical signs and nerve conduction studies (NCS). High resolution ultrasonography has emerged as feasible, economical and non-invasive imaging tool for evaluating median nerve in the carpal tunnel.

Aims of Study:

- To assess role of ultrasound in the diagnosis of carpal tunnel syndrome.
- To correlate ultrasound diagnosis with nerve conduction studies, considering nerve conduction studies as gold standard for diagnosis of carpal tunnel syndrome.
- To compare ultrasound parameters of median nerve in cases of carpal tunnel syndrome with an equal number of age matched healthy controls.

Material & Methods: The study was conducted on 73 patients with clinical diagnosis of carpal tunnel syndrome referred to the Department of Radiodiagnosis at DMCH Ludhiana over a period of one year. High frequency ultrasonography and nerve conduction studies were performed and data from both the investigations was correlated. Equal numbers of healthy controls were also taken and ultrasonographic parameters of the median nerve between the cases and controls were compared.

Results- In control group, the mean cross-sectional area of the median nerve was 0.07± 0.01 cm^2, while in cases it was 0.09 ± 0.03 cm^2 at both inlet and outlet.($p<0.001$) With a cut-off of 0.09 cm^2 for cross sectional area, sensitivity and specificity of ultrasonography in diagnosing CTS was 66% and 79% at inlet and 68 % and 80 % at outlet respectively. The overall sensitivity and specificity of Ultrasonography to detect CTS by increase in cross-sectional area compared to NCS was 70.42% and 80.00% respectively.

Conclusion: Because of its higher patient acceptability, lower cost, capability to assess carpal tunnel anatomy and good sensitivity/specificity, ultrasonography can be used as a screening modality with further use of NCS in cases where ultrasonography is non-diagnostic.

Keywords: Median Nerve, Sonography, Nerve Conduction studies.

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INTRODUCTION

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy of the upper limb owing to compression of the median nerve. CTS is a common problem with an estimated annual incidence rate of 0.5-5.1 per 1000[1,2] and is a major cause of loss of working days for workers, especially in hand intensive occupations.[1,3,4] Current trends of increase in its risk factors will likely result in an increased prevalence of CTS. Diabetes, obesity, an increasing life span and occupational risks are several of the contributing factors expected to increase the incidence rate.[5-7] As these trends increase, so too will the need for a reliable, non-invasive method of assessing and diagnosing CTS. Diagnosis of CTS often relies on a clinical diagnosis based on the patient's history, specific symptoms, and physical tests (Phalen's, Reverse Phalen's, Tinel, Carpal tunnel compression, Hand elevation tests), however atypical cases are often missed clinically.

More commonly, a clinical diagnosis of CTS is followed by confirmatory Nerve conduction studies (NCS). Nerve conduction studies evaluate the function of the median nerve, measuring the sensory and motor latencies, amplitudes, and velocities of the median nerve.[8] However, nerve conduction studies are invasive, uncomfortable, time-consuming, and costly. Additionally, high rates of false-positives, false-negatives and a wide range of sensitivities have been reported with NCS.[9,10]

Ultrasonography is widely available and non-invasive investigation which is cost-efficient, portable, and well tolerated by patients. The non-invasive nature and lack of radiation makes Ultrasonography (USG) an ideal modality for repeat examinations. Ultrasound has shown to be a useful diagnostic tool for CTS, providing information about median nerve anatomy and surrounding structures. Evaluation of the Cross-sectional area (CSA) of the median nerve, its echogenicity, vascularisation, and bowing of flexor retinaculum have been reported as beneficial parameters

for sonographically assessing CTS.[11-14] It has been proposed that sonography may replace NCS as a first-line test to confirm clinically diagnosed CTS, potentially eliminating the need for NCS in over 50% of the patients.[15,16] Evaluating multiple variables, both sonographic and clinical, provides a more inclusive assessment of physiologic changes in the median nerve.

Anatomy of Carpal tunnel

The carpal tunnel is a non-extendible osteofibrous tunnel defined as the space located between the flexor retinaculum, which forms the roof, and the carpal sulcus, which forms the base. It is delimited on the ulnar edge by the hamate hook, pyramidal bone and pisiform bone, and on the radial edge by the scaphoid bone, trapezoid bone and tendon of the flexor carpi radialis muscle. The base is formed by the capsule, and the anterior radiocarpal ligaments cover the underlying portions of the scaphoid, lunate, capitate, hamate, trapezium and trapezoid.[17]

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The median nerve is accompanied by four tendons from the superficial flexors of the fingers, four tendons from the deep flexors of the fingers and the long flexor of the thumb. The long flexor of the thumb is the most radial element. At the tunnel entrance, the median nerve is situated dorsally in relation to the long palmar muscle or between the flexor carpi radialis and the long palmar muscle. In neutral wrist position, the median nerve is in front of the superficial flexor of the index finger, or between the long flexor of the thumb and the superficial flexor of the index finger, or in front of the superficial flexor of the middle finger. In the distal part of the tunnel, the median nerve divides into six branches: the motor or thenar branch; three specific palmar digital nerves (radial and ulnar of the thumb and radial of the index finger); and the common palmar digital nerves of the second and third spaces.[17]

Just proximal to the wrist and carpal tunnel, the palmar cutaneous sensory branch arises, running subcutaneously to supply sensation over the thenar eminence.[18]

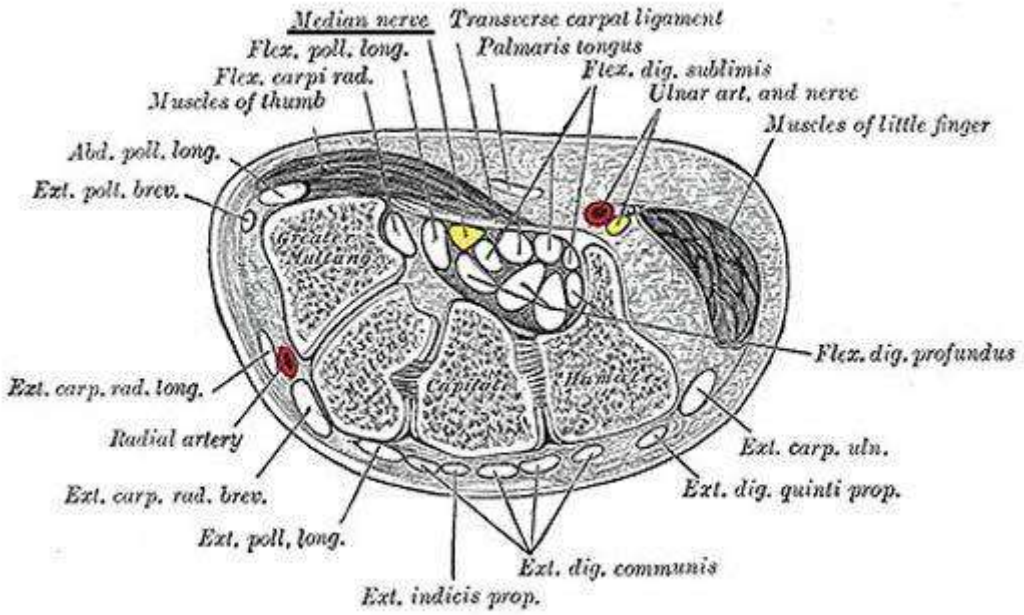

Fig 1: Diagrammatic representation of cross section of wrist[19]

Important Anatomical Variations

1.Bifid median nerve- The median nerve may divide into two nerve bundles in the distal forearm and appear as a bifid median nerve in the carpal tunnel. A bifid median nerve is observed in 1-3.3% of the cases.[17]

2.Persistent median artery- The persistent median artery of the forearm is an accessory artery that arises from the ulnar artery in the proximal forearm and is a persistent embryological remnant of the axial artery that usually regresses by eight weeks gestation. It is observed in 1–16% of the cases and usually associated with bifid median nerve. It gives rise to acute CTS, in case of thrombosis of this artery.[17]

ULTRASONOGRAPHIC ANATOMY

Like any peripheral nerve, the median nerve consists of multiple axons, which are grouped into fascicles surrounded by a dense perineurial sheath. Multiple fascicles interspersed by loose connective and adipose tissue combine into an individual peripheral nerve surrounded by an outermost sheath of the epineurium.[20]

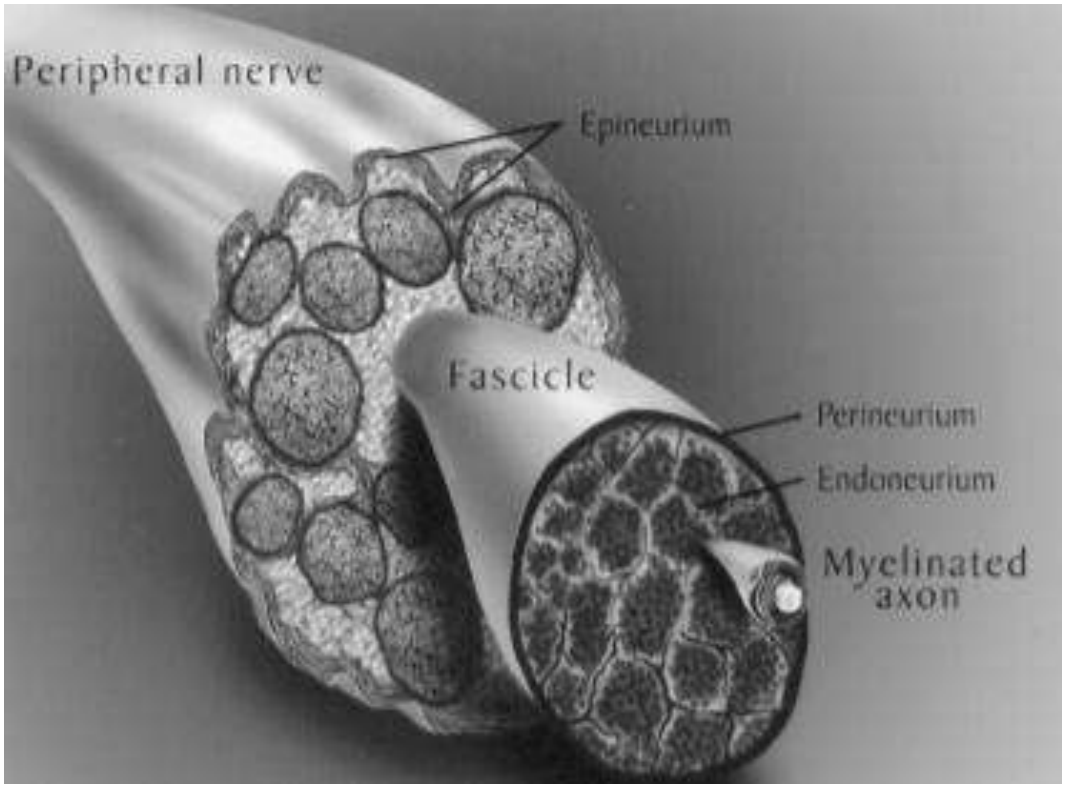

Fig 2: Diagrammatic representation of anatomic details of a peripheral nerve[20]

The sonographic presentation of a peripheral nerve correlates nicely with nerve ultrastructure. On longitudinal scans, hypoechoic tubular elements represent single fascicles. Tiny hyperechoic layers divide one fascicle from the other and a somewhat thicker hyperechoic surface (i.e., the outer epineurium separates the nerve as a whole from its surroundings.[21]

Fig 3: Longitudinal section of median nerve at the level of carpal tunnel [22]
MN-Median nerve T-Tendons

On cross-section, the nerve consequently exhibits a honeycomb appearance with tiny hypoechoic dots (the fascicles) interspersed and surrounded by a meshwork of hyperechoic connective tissue (the peri- and epineurium) [21]

Fig 4: Transverse section of median nerve at the level of carpal tunnel showing “Honey Comb” appearance of median nerve with hypoechoic fascicles (white arrows) [21]

Carpal Tunnel Inlet

The inlet of the carpal tunnel is taken as the proximal margin of the flexor retinaculum between the scaphoid tubercle and the pisiform bone. The transverse carpal ligament appears as a thin hyperechoic fascia extending from the pisiform to scaphoid bone. Immediately deep to the flexor retinaculum is the median nerve, followed by the 4 flexor digitorum superficialis tendons and the 4 flexor digitorum profundus tendons. The flexor pollicis longus tendon is just radial to flexor digitorum superficialis tendons and ulnar to the flexor carpi radialis. The ulnar vascular bundle is radial to the pisiform and superficial to the flexor retinaculum, next to the ulnar nerve.[23]

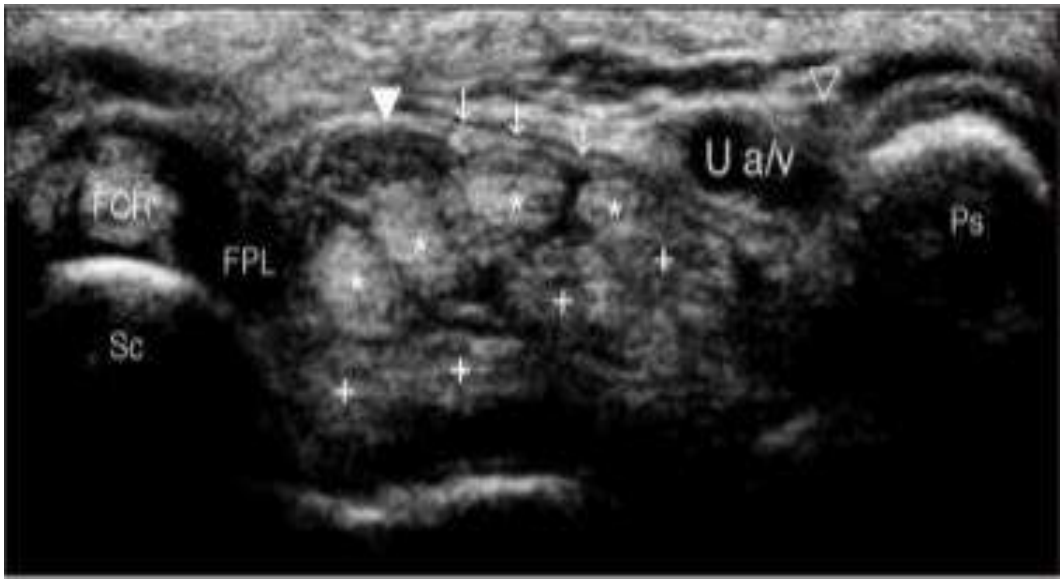

Fig 5: Ultrasonographic image of the carpal tunnel at inlet.[23]

Arrows-Transverse carpal ligament (Flexor retinaculum), Asterisks-Flexor digitorum superficialis tendons, FCR-Flexor carpi radialis, FPL-Flexor pollicis longus, Open triangle-Ulnar nerve, Plus signs-Flexor digitorum profundus tendons, Ps-Pisiform, Sc-Scaphoid; Solid triangle-Median nerve, U a/v- Ulnar artery and vein.

Carpal Tunnel Outlet

The tunnel outlet is situated at the distal margin of the flexor retinaculum. The bony border of the carpal tunnel outlet is formed by the trapezium

radially and the hook of the hamate ulnarly. The thenar and hypothenar muscles can be seen on each side superficial to bony structures. The ulnar artery is slightly superficial and radial to the hook of the hamate. Due to thick transverse carpal ligament blocking transmission of sound beams, the anatomy at the carpal tunnel outlet appears relatively hypoechoic. Therefore, it is difficult to appreciate each individual fascicle in the median nerve at the outlet.[23]

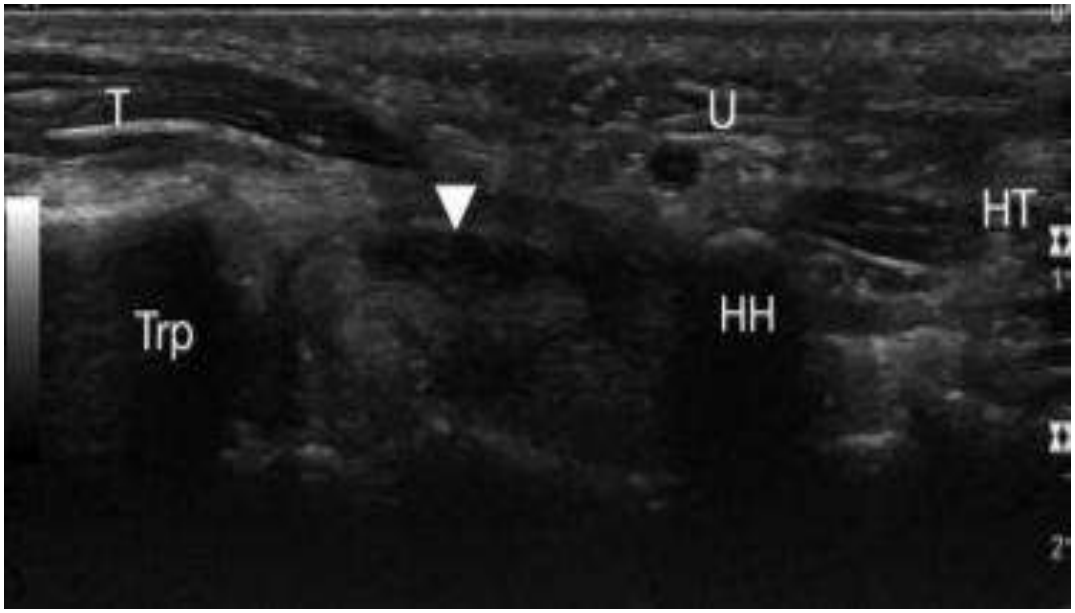

Fig 6: Ultrasonographic Image at the carpal tunnel outlet [23]

T-Thenar muscles, HT-Hypothenar muscles, Triangle- Median nerve, U-Ulnar nerve, Trp-Trapezius & HH-Hook of hamate

Etiology of Carpal Tunnel syndrome

There are two distinct varieties of CTS - acute and chronic. The acute form is relatively uncommon and is due to a rapid and sustained rise of pressure in the carpal tunnel. This is most commonly associated with a fracture of the radius. The chronic form is much more common and symptoms can persist for months to years. However, in only 50% of cases is the cause identified, and can be divided into local, regional and systemic causes.[24]

A. Local causes[24]

- Inflammatory: e.g. tenosynovitis, histoplasma fungal infection, hypertrophic synovium
- Trauma: e.g. Colles' fracture.
- Tumors: e.g. Haemangioma, cyst, ganglion, lipoma, neuroma etc.
- Anatomical anomalies: e.g. thickened transverse carpal ligament, bony abnormalities, abnormal muscle bellies, persistent median artery etc.

B. Regional causes[24]

- Osteoarthritis
- Rheumatoid arthritis
- Gout
- Amyloidosis

C. Systemic causes[24]

- Diabetes
- Obesity
- Hypothyroidism
- Pregnancy-(Commonly diagnosed during third trimester & often bilateral)[25,26]
- Systemic lupus erythematosus
- Scleroderma
- Dermatomyositis
- Renal failure
- Long-term haemodialysis
- Acromegaly
- Sarcoidosis
- Leukemia
- Alcoholism
- Haemophilia

Role of Occupation

Carpal tunnel syndrome is one of the common forms of Repetitive Trauma disorder.[27] Brain et al were the first to implicate occupation as a causal factor in CTS.[28] At-risk occupations include grinders, cashiers, and meat packers, workers sewing car seats, aircraft engineers, grocery store workers, and small part assembly liners etc.

The physical factors implicated and extensively studied in relation to occupational CTS include repetition, force, posture, external pressure, and vibration.

Repetition is the most widely recognized risk factor for occupational CTS. A high repetitive job is defined as one which involves the repetitive use of awkward wrist movements lasting less than 30s or when more than 50% of work time is spent performing tasks that involve repetitive awkward wrist movement.[24] CTS is strongly associated with high force-high repetitive work and to a lesser extent with high repetitiveness alone, irrespective of other factors. High force combined with high repetitiveness has more than a multiplicative effect, increasing the risk more than 5 times that of either factor alone.[29]

Awkward hand postures or vibration may also be important risk factors for CTS. Studies have found evidence for an association between non-neutral wrist posture in extension or flexion and work-related CTS. In a meta-analysis done by Doohee You et al, it was concluded that prolonged exposure to non-neutral wrist postures is associated with a twofold increased risk for CTS compared with low hours of exposure to non-neutral wrist postures.[30] Similarly, studies have showed that regular use of hand-held vibrating tools increased the risk of Carpel tunnel syndrome by more than 2-folds.[3]

Preventive measures to avoid occupation related CTS may include: (i) job rotation (ii) rest breaks (iii) task optimisation (iv) training (to ensure better working practices) (v) an induction period, to allow new employees to start out at a slower pace (vi) a rehabilitation programme.[3]

Pathogenesis-

The pathophysiology of CTS involves a combination of mechanical trauma, increased pressure and ischemic injury to the median nerve within the carpal tunnel.[31]

Increased carpal tunnel pressure

Normal pressure in the carpal tunnel has been recorded to range from 2 to 10 mmHg.[32,33] Pathological changes occurring in the ligaments surrounding nerves including alterations in the amount and flexibility of connective tissue are thought to be the basis for increased pressure. Anatomically, there are 2 sites of median nerve compression: at the proximal edge of the carpal tunnel and at the narrowest portion at the hook of hamate. Experimental studies have suggested a dose-response curve relationship i.e. the greater the duration and amount of pressure, the more significant is the neural dysfunction.[33]

Median nerve microcirculation injury

It includes ischemic vascular injury and the breakdown of the blood-nerve barrier. Ischemic injury has been identified as an essential component in CTS by Gelberman et al.[34]

Vascular changes in CTS occur in three stages:

Stage I Venous congestion

Stage II Nerve edema resulting from anoxic damage to the capillary endothelium.

Stage III Impairment of both venous and arterial blood supply.[35]

The blood-nerve-barrier is formed by the inner cells of the perineurium and the endothelial cells of endoneurial capillaries that accompany the median nerve through the carpal tunnel. These endoneurial microvessels are formed from nutrient branches that arise from the radial and ulnar arteries, proximal to the flexor retinaculum. An increase in pressure within the tunnel can cause a breakdown of vasculature within this barrier, causing an accumulation of proteins and inflammatory cells.[36]This induces a miniature closed compartment syndrome by increasing the permeability,

contributing to increased endoneurial fluid pressure and development of intra-fascicular edema.[37] Nerve compression also causes changes in the microvascular structure of the nerve as well, which also leads to reduction in the endoneurial blood flow and oxygen tension. The development of edema may lead to an increase in the diffusion distance for oxygen from the capillaries, which could lead to hypoxia and resultant axonal degeneration.[33]

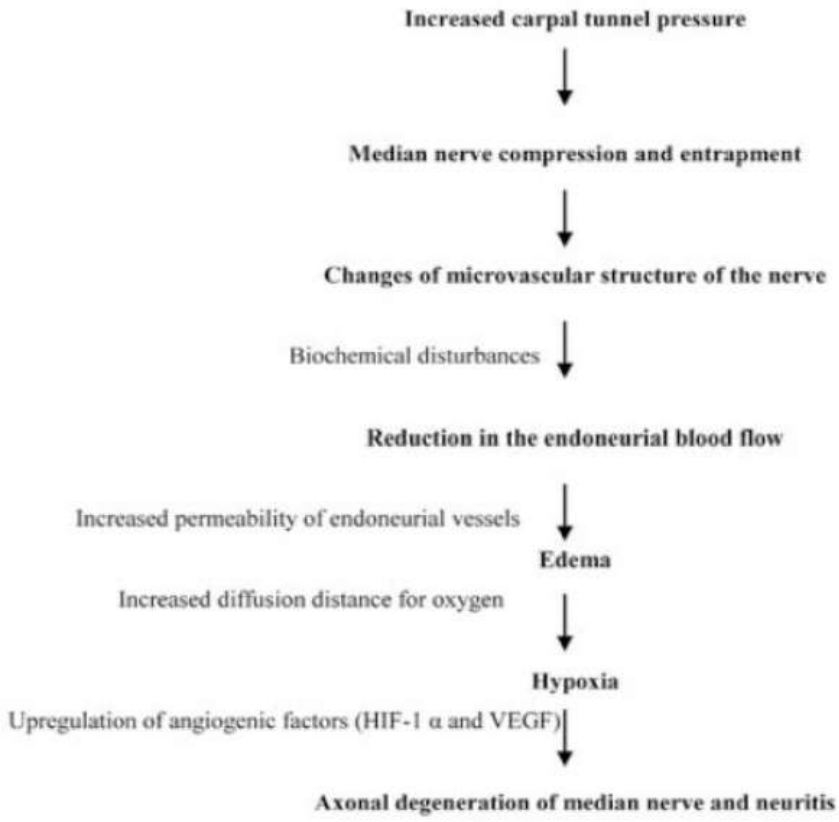
Increased carpal tunnel pressure
Median nerve compression and entrapment
Changes of microvascular structure of the nerve
Biochemical disturbances
Reduction in the endoneurial blood flow
Increased permeability of endoneurial vessels
Edema
Increased diffusion distance for oxygen
Hypoxia
Upregulation of angiogenic factors (HIF-1 α and VEGF)
Axonal degeneration of median nerve and neuritis

Fig 7: Schematic representation of pathophysiology of CTS [33]

Synovial tissue hypertrophy

Hypertrophy of the synovial tissue of the flexor tendons can increase the pressure in the carpal tunnel and result in the development of CTS.[33] Studies have reported tenosynovitis as a closely related risk factor to the development of idiopathic CTS.[38]The inflammatory thickening of the synovial tissue increases the volume of tissue which in turn increases the

fluid pressure within the carpal tunnel. The most profound thickening of synovial tissue occurs at the entrance and exit regions of the canal, where the tendons slide over a fulcrum of the flexor retinaculum. Strain and micro-damage to the synovial tissue as well as the median nerve can occur due to the different degrees of excursion between the flexor tendons and the median nerve. Constrictive scar tissue may also form around the median nerve, which in turn can result in tethering of the nerve.[33,39]

Nerve Demyelination

An important step in injury to the median nerve is demyelination, which occurs when the nerve is repetitively subjected to mechanical forces. Demyelination of the nerve develops in the compression site, and can then spread to the entire inter-nodal segment, leaving the axons intact.[31]

Clinical features of carpal tunnel syndrome

Patients with carpal tunnel syndrome typically complain of pain**,** numbness & paraesthesias throughout the median nerve sensory distribution. The portion of the hand involved is classically the thumb, index and middle fingers, and radial half of the ring finger. The palm is often spared, due to the palmar cutaneous branch of the median nerve branching proximal to the flexor retinaculum and passing over the carpal tunnel.

Symptoms are typically worse during the night (brachialgia paraesthetica nocturna) and symptoms can often be temporarily relieved by hanging the affected arm over the side of the bed or by shaking it back and forth.

In the later stages of carpal tunnel syndrome, there may be weakness of thumb abduction (due to denervation atrophy of the thenar muscles) and / or wasting of the thenar eminence.

Clinical Tests

Tinel sign and Phalen's test are widely used provocative tests for assessing median nerve compression.

1. Tinel's sign

It was described by Tinel in 1915.[40]In this test, the examiner taps lightly over the site of the median nerve at the distal wrist crease and is considered positive, if tapping causes pain and paraesthesia in median nerve distribution.

The reported sensitivity and specificity of Tinel test was 53.4 and 95.6% respectively by Rayegani et al.[41]

2. Phalen test

It is performed the test by having the patient hold the forearm vertically with the elbows resting on the table and then allowing both hands to drop with complete wrist flexion for approximately one minute. The test is considered positive when paresthesia develops in less than one minute.[42] The test shows sensitivity of 58% and a specificity of 54% according to a study by Buch-Jaeger et al.[43]However, Rayegani et al reported it to be respectively 67.2% and 92.9%respectively.[41]

Diagnostic Modalities

Ultrasonography- High-resolution ultrasonography has become one of the most important techniques for imaging of peripheral nerves and therefore in carpal tunnel syndrome. Apart from acting as a useful adjunct to NCS, it is quite useful in diagnosing secondary causes of CTS such as tenosynovitis, ganglia or other tumors, accessory muscle tissue and even vascular anomalies (a persistent median artery, aneurysms or vascular malformations).[44] Furthermore, Color Doppler imaging has also presented as reliable complementary tool and correlates strongly with the severity of carpal tunnel syndrome.[45] At the therapeutic level, interventional ultrasonography provides guidance for carpal tunnel injections that makes the procedure safer and that allows complications due to intraneural injection to be avoided.

Advantages of Ultrasonography-

1. Painless and Non-Invasive
2. Cost effective
3. Dynamic Imaging
4. Widely available
5. Assesment of secondary causes of CTS.
6. Role in ultrasound guided steroid injections

Limitations

Operator-dependent limitations

Ultrasonographic findings in carpal tunnel syndrome-[46]

- Increased cross-sectional area proximal to the compression site, usually at the level of the proximal pisiform bone(In normal conditions, the cross-sectional area of the median nerve is not greater than 9 mm^2)
- Lower echogenicity and blurred echotexture
- Nerve flattening- in the transverse section, the nerve is at least 3 times wider than it is thick; the thickness is not greater than 2 mm.
- Palmar Bowing- Bulging of flexor retinaculum by at least 4 mm above the line that connects the ventral edge of the hook of the hamate bone with the tubercle of the trapezium.
- Increased vascularization in a Color Doppler examination.
- Increased Inlet to Outlet Ratio.[11]
- Hourglass-like narrowing of the nerve in the longitudinal section, corresponding to the compression site. It can present as:

  Notch – an image of a sudden narrowing at the level of the proximal border of the compression site

  Inverted notch – an image results from a sudden increase in nerve thickness at the level of the distal border of the compression site.

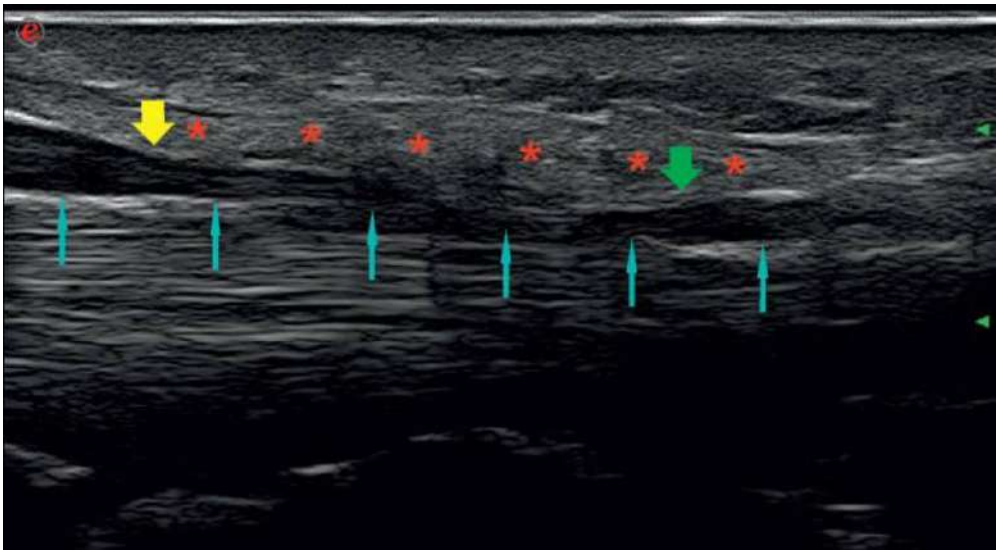

Fig 8: Longitudinal section at level of carpal tunnel depicts median nerve compression: blue arrows – median nerve; yellow arrow – notch sign; green arrow –inverted notch sign; red arrow – flexor retinaculum

- Decrease or absence of nerve movability in the carpal tunnel
- Difference in median nerve cross-sectional areas between the level of the proximal pisiform bone and proximal part of the pronator quadratus muscle is at least 2 mm^2

Magnetic resonance imaging

Because of its inherently high contrast, which allows accurate depiction of the soft tissue structures of the wrist, MRI is a valuable imaging technique of diagnostic value in CTS. MRI has been shown to be a valid and reproducible technique for measuring carpal tunnel volume and the cross-sectional area of the flexor tendons and the median nerve.[47] Diagnostic criteria for carpal tunnel syndrome on MRI are similar to those on ultrasound: namely, bowing of the flexor retinaculum, enlargement of the proximal median nerve and flattening of the distal nerve.

The carpal tunnel can be best evaluated in the transverse plane. A comparison of T1, proton-density and T2 weighted pulse sequences shows that both the median nerve and the general morphology can be

best assessed in the proton-density weighted images. They are superior in demarcating the median nerve as well as demonstrating additional lesions which could be identified as causes of nerve compression. In cases of pronounced oedema of the nerve, inflammatory joint effusion or acute tenosynovitis the visualization is better in T2-weighted images. Only in patients with pathological alterations of wrist bones in rheumatoid arthritis or after fractures T1-weighted images provide important information.[48] Fibrosis of the median nerve (low T2 signal) as a sign of advanced CTS can be differentiated from nerve oedema (high T2 signal) in early CTS helping in staging of the disease.

Advantages

- Non-Invasive
- Better contrast resolution than ultrasonography
- Role in staging of disease

Disadvantages

- Time consuming
- High cost
- Sensitive to patient motion artifacts
- Claustrophobia
- Metallic implants or foreign bodies may produce magnetic susceptibility artifacts.

Nerve conduction studies

Nerve conduction studies are still considered to be the gold standard in diagnosis of CTS. The results of nerve conduction studies have been found to be highly sensitive and specific for the diagnosis of CTS.[9,49] The nerve conduction studies include the sensory and motor nerve studies.

Sensory Conduction studies

The sensory response in these studies is composed of individual sensory nerve fiber action potentials and is referred to as a compound sensory nerve action potential (SNAP). The response is termed “antidromic” when the recording electrodes are placed distal to the stimulating electrodes

(the recorded action potentials traverse the nerve opposite to the physiologic direction) and “orthodromic” when they are located proximal to the stimulating electrodes (the recorded action potentials traverse the nerve in the physiologic direction). Other measured parameters include latency, conduction velocities, and negative phase duration.

In early and mild CTS, mild sensory nerve conduction slowing across the carpal tunnel is often the only abnormal finding. Using antidromic techniques with stimulation applied to the wrist, median SNAPs can be recorded at the thumb, the index, the long, and the ring fingers.

Median sensory fiber electrical signals can also be recorded in the long finger with the application of two stimuli, one at the wrist and one at the palm. When present, relative sensory nerve conduction slowing in the proximal segment can reveal focal median sensory nerve injury localized to the carpal tunnel.[50,51]

Motor Conduction studies

In motor NCSs, the stimulating electrodes are applied over the nerve and the recording electrodes are placed over the muscle, so the motor response is composed of muscle fiber action potentials (rather than motor nerve fiber action potentials) and is referred to as a compound muscle action potential. Various measurements taken from motor responses include amplitude, latency, nerve conduction velocity (NCV). The most commonly used test is the median distal motor latency (DML), obtained by recording over the abductor pollicis brevis muscle with stimulation at the wrist. Others include (1) the absolute value of the DML of the compound muscle action potential of the second lumbrical muscle (2) comparison of the motor latency of the CMAP of the lumbrical muscle with that of the interosseous muscle after stimulation of the median and ulnar nerve and(3) the terminal latency index of the thenar CMAP.

Although median motor nerve conduction studies are less sensitive than sensory nerve conduction studies, they are important in the documentation of motor fiber involvement in CTS especially in severe

cases, where sensory nerve action potentials may not be recordable. In these cases, motor nerve conduction studies are the only electrophysiological means to confirm the clinically defined diagnosis of CTS.[51]

Advantages-

High specificity and sensitivity

High Reproducibility

Objective criteria for diagnoisis

Disadvantages-

Painful

Costly

Lower acceptability

Treatment

Various treatment modalities for CTS include stretching exercises, local corticosteroid injection, splinting (immobilizing braces), oral corticosteroids and surgical release of flexor retinaculum.

AIMS AND OBJECTIVES

- To assess role of ultrasound in the diagnosis of carpal tunnel syndrome.
- To correlate ultrasound diagnosis with nerve conduction studies, considering nerve conduction studies as gold standard for diagnosis of carpal tunnel syndrome.
- To compare ultrasound parameters of median nerve in cases of carpal tunnel syndrome with an equal number of age matched healthy controls.

REVIEW OF LITERATURE

Many studies have been published to date, which evaluate the role of ultrasound as a relevant diagnostic modality in carpal tunnel syndrome.

Buchberger et al (1992) studied typical anatomic changes seen in CTS using high-resolution sonography and MRI imaging in twenty wrists in 18 consecutive patients. The characteristic findings on imaging of the 20 wrists with carpal tunnel syndrome included swelling of the median nerve in the proximal part of the carpal tunnel in 16 wrists, flattening of the median nerve in the distal part of the carpal tunnel in 13 wrists, and increased palmar bowing of the flexor retinaculum in nine wrists. A comparison with the data of 28 normal wrists proved that these findings were significant (p less than 0.01 to p less than 0.001).[14]

Lee et al (1999) conducted a study in three phases in order to clarify the carpal tunnel anatomy, elucidate the ultrasound characteristics of the median nerve and the carpal tunnel, develop an understanding of the ultrasound changes with pathology, and finally evaluate the potential of ultrasound as a diagnostic tool for CTS.

Phase 1 was devoted to understanding the normal median nerve anatomy and determining its ultrasound characteristics.

The purpose of phase 2 was to establish ultrasound changes associated with CTS. Median nerves in 16 patients (both pre and post-operative) with CTS were imaged using a 7.5-MHz linear-array transducer on a Dornier, Acoustic Imaging (Model 5200) ultrasound system in both longitudinal and transverse orientations. The median nerve demonstrated consistent and statistically significant increases in cross-sectional area. Longitudinally, abrupt contour changes along its course were noted to varying degrees, relative to the amount of increase in the cross-sectional area. Overall, in both men and women, the mean cross-sectional area of the median nerve affected by CTS was 18.2 mm^2 (SD = 2.1). Ultrasound of the carpal tunnel and the median nerve was found to be a reliable and repeatable method

to demonstrate small morphologic changes in the median nerve associated with CTS.

In phase 3, a double-blind study was done in which results of ultrasound were compared with Electromyography (EMG) used as the gold standard in known cases of CTS. Results showed excellent correlation between the median nerve cross-sectional area measurements by ultrasound and EMG findings.[52]

Duncan et al (1999) evaluated the use of sonographic measurements of the median nerve in the diagnosis of carpal tunnel syndrome. The authors studied 68 carpal tunnel syndrome patients (50 women, 18 men) with 102 affected nerves and 68 nerves in 36 asymptomatic controls (23 women, 13 men) and measured the median nerve cross-sectional area and the maximum transverse and antero-posterior diameters at the proximal boundary of the carpal tunnel. Data comparison between the patient group and the control group revealed that the most predictive measurement was swelling of the median nerve, which was significantly greater in carpal tunnel syndrome patients compared with controls (mean, 0.13 cm^2 versus 0.07 cm^2). It was concluded that the quantitative assessment of the median nerve proved to be an accurate diagnostic test (sensitivity, 82%; specificity, 97%), with an area larger than 0.09 cm^2 being highly predictive of carpal tunnel syndrome.[53]

In order to evaluate sonographic signs of carpal tunnel syndrome, Sarría et al (2000) evaluated sixty-four wrists from 40 patients with CTS (confirmed by electromyography) and 42 wrists from 24 healthy individuals using sonography. Cross-sectional area, flattening ratio in proximal, middle and distal segments of the carpal median nerve and bowing of the flexor retinaculum were measured in the study. A significant swelling of the median nerve was observed at the proximal ($p < 0.001$), middle ($p < 0.0001$) and distal ($p < 0.0001$) segments and a significant bowing of the flexor retinaculum in CTS patients with respect to healthy subjects. No significant differences were found in the mean value of flattening ratio

between the groups. The sensitivity, specificity, positive predictive value, and the negative predictive value were calculated to be 73.4%, 57.1%, 72.3% and 58.5%,respectively, in the proximal and middle segments; 75%, 57.1%, 72.7% and 60% in the distal segment for areas greater than 11 mm^2; and 81.3%, 64.3%, 77.6% and 69.2 % for the bowing of the flexor retinaculum greater than 2.5 mm. The most reliable sign suggesting CTS was found to be increased bowing of the flexor retinaculum and cross-sectional area of median nerve with specificity close to 60%.[54]

Swen et al in 2001 conducted a study comparing sensitivity and specificity of sonography and nerve conduction studies in CTS diagnosis in Sixty-three patients. The sensitivity to detect CTS was found to be 0.70 for sonography and 0.98 for NCS, and specificity was 0.63 for sonography and 0.19 for NCS, thus concluding that sonography had better sensitivity when compared with NCS.[55]

In a bid to study the usefulness of nerve cross-sectional area in the diagnosis of CTS, Nakamichi et al (2002) made ultrasonographic measurements of the nerve area at the distal (distal edge of the flexor retinaculum), mid (hook of the hamate), and proximal carpal tunnel (wrist crease) in 414 wrists of 275 patients with clinically diagnosed idiopathic CTS and 408 wrists of 408 controls. They found that the criteria based on the area at single level yielded sensitivities of 43-57% and specificities of 96-97%. Use of the mean carpal nerve area (average of the areas at the three levels) was found to improve the results (sensitivity, 67%; specificity, 97%), and was as sensitive as the nerve conduction studies (NCS). Furthermore, a combination of the mean carpal nerve area and NCS criteria was found to yield a sensitivity of 84% and a specificity of 94%.[56]

Wong et al (2002) studied different sonographic criteria in diagnosing CTS and compared sonograms of 35 patients with that of healthy subjects in a case-control study. Eight separate sonographic criteria including cross sectional areas of nerve at various levels, flattening ratio, palmar bowing and retinacular thickness were analyzed in each wrist. The increased

cross-sectional area of the median nerve was found to be the most predictive measure of carpal tunnel syndrome, proximal to the tunnel inlet, at the tunnel inlet, and at the tunnel outlet, with significant differences between patients and controls. Using receiver operating characteristic curves, a cut-off value >0.098cm² at the tunnel inlet was observed to provide a diagnostic sensitivity of 89% and a specificity of 83%.[57]

El Miedany et al (2004) studied optimal discriminatory sonographic criteria and relevant threshold sonographic values in patients with CTS and evaluated role of quantitative ultrasonography as a tool for diagnosis and treatment of patients suffering from carpal tunnel syndrome in comparison with electrophysiological study. In a study of 78 patients with CTS and 78 asymptomatic controls, it was observed that various levels of disease severity could be illustrated by USG and a cut-off point of 10 mm² for the mean cross-sectional area of the median nerve was found to be the upper limit for normal values. Further, it was concluded that High Frequency ultrasound examination of the median nerve and measurement of its cross-sectional area could be strongly considered as a new alternative diagnostic modality for the evaluation of CTS. In addition to being of high diagnostic accuracy, it was able to define the cause of nerve compression, aided treatment planning and provided a reliable method for following the response to therapy.[58]

Ziswiler et al (2005) conducted a prospective study to determine the diagnostic value of sonography in patients with suspected carpal tunnel syndrome (CTS). They studied 110 wrists in 74 consecutive patients with suspected CTS who had been referred to a tertiary care center and determined the largest cross-sectional area of the median nerve at the carpal tunnel. Because of the lack of a universally accepted reference standard, they first examined the association of sonography with nerve conduction and then compared sonography with a reference standard based on the combination of nerve conduction studies and signs and symptoms. Sonography and reference standard tests were performed

independently and interpreted under blinded conditions. Based on a fitted receiver operating characteristic curve, likelihood ratio (LR) and posttest probabilities were estimated for different cutoffs. A high concordance was found between sonography and nerve conduction. Based on the combined reference standard, a cut-off of 10 mm² was found to result in approximately equal sensitivity and specificity, but only moderate LRs. A cutoff of <8 mm² was found to have satisfactory power to rule out CTS: the fitted-negative LR was 0.13. Conversely, a cutoff of > or =12 mm² was showed to have excellent power to rule in CTS, with a fitted-positive LR of 19.9. For nerves > or =12 mm² and a pretest probability of 70% expected in patients with suspected CTS in tertiary care, they found a post-test probability of CTS of 98%. It was concluded that different cutoff values for the largest cross-sectional area may be used to accurately rule in or rule out CTS and sonography as a first-line test could cost-effectively reduce the number of nerve conduction studies in patients with suspected CTS.[59]

Karabaty et al in 2005 used high resolution ultrasound to quantify flattening of the median nerve in CTS and to calculate flattening ratio before endoscopic carpal tunnel release as well as 2 weeks and 3 months postoperatively in ten patients with clinical and electrophysiological confirmed CTS. It was found that there was significant normalization of the calculated flattening ratio of the median nerve within 2 weeks after surgical release, whereas nerve conduction studies needed a longer period of time to normalize and were still abnormal 3 months postoperatively. They concluded ultrasound to be a simple and excellent objective method for visualizing the morphological recovery of the median nerve very early after decompression surgery. In complex cases with the unsatisfactory outcome, ultrasonography proved to be useful in confirming successful or failed decompression of the median nerve.[60]

Wiesler et al (2006) documented the ultrasonographic measurement differences in median nerve cross sectional area at distal wrist crease between 26 patients with CTS and 43 controls and correlated these

findings with NCS findings. The average cross-sectional area of the median nerve at the distal wrist crease was found to be 9 mm² in asymptomatic volunteers and 14 mm² in CTS patients. For the CTS patients, the Pearson correlation coefficient between ultrasound nerve measurement and NCS values was 0.37, suggesting that higher values of ultrasound measurements are associated with abnormal NCS findings.[61]

Mallouhi et al (2006) retrospectively assessed the accuracy of gray-scale and colour doppler sonography in the diagnosis of carpal tunnel syndrome in 206 wrists in 151 patients with clinical suspicion of carpal tunnel syndrome using nerve conduction studies as the standard of reference. In the results of the study, it was found that in comparison to the nerve conduction studies, nerve swelling showed the highest accuracy (91%) among gray-scale sonography criteria, and the presence of intraneural hypervascularization showed the highest accuracy (95%) among all sonography criteria. Logistic regression analysis of the data showed that nerve hypervascularization was the only variable that independently predicted median nerve entrapment (odds ratio, 16.4; 95% confidence interval, 8.7-31.1; $p < 0.001$), thereby concluding that Color Doppler sonography is more accurate than gray-scale sonography for characterizing median nerve involvement in patients with suspected CTS.[62]

With the purpose to study the most adequate cut-off point of median nerve cross-sectional area in diagnosing CTS, Sernik et al (2007) measured cross-sectional area of median nerve in forty wrists from 31 CTS patients and 63 wrists from 37 asymptomatic volunteers were using direct and indirect techniques. The study concluded that median nerve diameter cut-off point of 10 mm^2 (direct technique) and 9 mm^2 (indirect technique) were both sensitive and specific in diagnosing CTS.[63]

Mohammadi et al (2010) studied the role of high resolution ultrasonography as an alternative diagnostic method to nerve conduction study in CTS and the use of cross-sectional area of median nerve in

grading the severity of carpal tunnel syndrome. Cross-sectional areas of the median nerve were measured bilaterally at the carpal tunnel inlet and outlet in 164 wrists of 82 patients with NCS confirmed carpal tunnel syndrome. The comparisons between ultrasonography and NCS were made and severity grading done using nerve conduction study as a gold standard reference. The mean median nerve cross-sectional area found at the tunnel inlet was 11.4±1.7 mm^2 for the carpal tunnel syndrome affected wrist and 5.78±0.9 mm^2 for the normal wrist (P<0.001). The mean median nerve cross-sectional area at the tunnel outlet was 9.9±1.2 mm^2 for the affected wrist with carpal tunnel syndrome and 4.7±0.7 mm^2 for the normal wrist (P<0.001). The best cutoff value of cross-sectional area at the tunnel inlet and outlet was found to be 8.5 mm^2. The difference in cross-sectional area of the median nerve in mild, moderate and severe carpal tunnel syndrome was not found to be statistically significant (P=0.2) neither in the carpal tunnel inlet nor outlet. The study concluded that cross-sectional area of median nerve ultrasonography had a diagnostic value to confirm or exclude CTS, but could not be used for grading its severity.[64]

Ghasemi et al (2011) assessed the role of intraneural vascularity seen at Color Doppler ultrasonography to diagnose CTS and evaluated use of an image processing method to quantify the severity of CTS on the basis of this vascularity. A total of 100 patients with clinical evidence of CTS and 55 healthy controls were examined with Electrodiagnostic tests (EDT) and color doppler USG and an image processing program was used to determine the sum of pixels in the intraneural vascular area. The sensitivity (83%) and specificity (89%) of intraneural vascularity in the diagnosis of CTS were found to be similar to those of EDT (81% and 84%, respectively). Intraneural vascularity was seen in 91.4% of patients with mild CTS and 100% of patients with moderate or severe CTS concluding that Color Doppler USG could, therefore be used to accurately diagnose CTS. In participants with positive intraneural vascularity, the sum of pixels in the intraneural vascular area was significantly higher in patients than in

control subjects and paralleled the severity of the abnormality at EDT (P,.01), allowing accurate assessment of disease severity.[65]

Similarly, Joy et al in a retrospective analysis suggested that adding measures of intraneural blood flow to CSA further improved the sonographic evaluation of CTS. The results revealed that raised intraneural blood flow showed the highest test sensitivity in diagnosing carpal tunnel syndrome (83%) and combined with CSA sensitivity reached 90% in the highly likely CTS group.[66]

Ghaffar et al in their study on 41 patients with clinically suspected CTS found a definitive role of grey scale and color doppler ultrasonography in diagnosis of CTS. The results showed that median nerve swelling had the highest accuracy (89%) among the gray scale sonographic criteria, and the presence of median nerve hypervascularization showed the highest accuracy (94%) among all sonographic criteria. These findings were in concordance with study done by Mallouhi et al in 2006.[67]

Tengfei et al in 2015 evaluated the diagnostic value of the Inlet to Outlet median nerve area ratio (IOR) in patients with clinically and electro-physiologically proven CTS. The study was done on forty-six wrists in 46 consecutive patients with clinical and electrodiagnostic evidence of CTS and forty-four wrists in 44 healthy volunteers. The mean IOR in healthy volunteers (1.0) was found to be smaller than that in patients (1.6, $P<0.001$). The mean inlet CSA was 8.7 mm^2 in healthy controls and 14.6mm^2 in CTS group ($P<0.001$). Receiver operating characteristic analysis revealed a diagnostic advantage to using the IOR rather than the inlet CSA ($P<0.01$). An IOR cutoff value of ≥ 1.3 was found to yield 93% specificity and 91% sensitivity in the diagnosis of CTS.[11]

Furthermore, Zhang et al (2015) found in his study that there were significant differences in the inlet-to-outlet ratio patients with mild, moderate, and severe carpal tunnel syndrome. The calculated cut-off point in the ratio of cross-sectional areas of the median nerve was 1.29 between mild and more severe (moderate and severe) carpal tunnel syndrome

patients with 64.7% sensitivity and 72.7% specificity. The cut-off point in the ratio of cross-sectional areas of the median nerve was calculated to be 1.52 between the moderate and severe carpal tunnel syndrome patients with 80.0% sensitivity and 64.7% specificity. Therefore, in conclusion, the inlet-to-outlet ratio was useful in assessing the severity of carpal tunnel syndrome.[68]

Kanikannan et al (2015) compared the diagnostic accuracy of high-resolution ultrasonography with electrodiagnostic testing in a prospective cohort of 57 Indian patients and 50 matched controls. The results revealed that Ultrasonography had good correlation with electro-diagnostic studies in all grades of CTS. Mean CSA at the inlet of carpal tunnel was 0.11 ± 0.0275 cm^2 and had the sensitivity, specificity, positive predictive value and negative predictive values of 76.43%, 72.72%, 89.47% and 68%, respectively ($P < 0.0001$).Furthermore, the authors recommended the use of High Resolution Ultrasonography as a complementary screening tool to Electrodiagnostic testing.[69]

With the aim to evaluate median nerve CSA using sonography in CTS in an Indian setup, Kamath et al conducted a prospective study in 30 patients undergoing diagnostic workup for carpal tunnel syndrome in the pre-treatment period with 30 healthy participants as controls. Data from the study revealed that that best discriminatory criterion for diagnosis of carpal tunnel syndrome are median nerve cross sectional area in the proximal part of carpal tunnel ≥9 mm^2 (Direct method) and ≥8.5 mm^2 (Indirect method). Also, there was significant difference in flattening ratio between cases and controls with the mean flattening ratio in distal part of tunnel (at the level of hook of hamate) was 2.97 and 2.38 in cases and controls respectively. The authors recommended Ultrasonography as a reliable modality in diagnosing CTS, more so because it's non-invasive and accurate nature.[70]

Ugwu et al (2017) studied the influence of occupation and hand dominance on median nerve cross-sectional area in 180 apparently

healthy volunteers grouped into repetitive and non-repetitive work groups based on their occupation. The median nerve cross-sectional area was significantly higher ($P < 0.05$) in the repetitive work group than in non-repetitive work groups. Similarly, a significant difference in the mean median nerve CSA was observed in dominant and non-dominant hands in the repetitive work group ($P < 0.05$). However, there was no significant difference in the mean median nerve CSA in the non-repetitive work groups ($P < 0.05$). The authors concluded that occupation and hand dominance affected the cross-sectional area of the median nerve.[71]

Da Sol Ha et al (2017) evaluated the relationship between electrophysiologic severity of CTS and the ultrasonographic indexes including cross-sectional area (CSA) of the median nerve, CSA of the carpal tunnel and nerve/tunnel index in 54 female patients. They found out that the proximal CSAs of the median nerve and carpal tunnel increased in CTS patients and severity by electrodiagnostic results statistically correlated to the proximal CSA of the median nerve and carpal tunnel. However, no relationship was found between the proximal and distal nerve/tunnel indexes and the severity by electrodiagnostic results.[72]

Dynamic ultrasonography has also shown promising results as a potential diagnostic tool in CTS as evidenced by the study done by Park et al (2018). It was found that the mean grade of median nerve mobility in the CTS group (1.9) was significantly lower than that in the control group (2.6; $P < 0.001$). There were significant negative correlations between the grade of median nerve mobility and distal motor latency of the median nerve ($r ¼ –0.218$, $P ¼ 0.015$), neurophysiological grading scale ($r ¼ –0.207$, $P ¼ 0.020$) and CSA of the median nerve ($r ¼ –0.196$, $P ¼ 0.028$). Furthermore, the grade of median nerve mobility was negatively correlated with the severity of CTS, thus allowing accurate determination of diagnosis and severity of CTS.[73]

Peng lin et al (2019) in his meta-analysis of 17 studies, reviewed the role of ultrasound elastography in the evaluation of CTS. They concluded that

ultrasound elastography (tissue strain, strain ratio, shear modulus and shear wave velocity) could be potentially used in diagnosing CTS and categorizing its severity.[74]

Singla et al (2020) evaluated the role of High Frequency Ultrasonography as a tool for diagnosis in patients with CTS in comparison with electrophysiological study. On comparison, data from the patient and the control groups showed a high degree of correlation between the conduction abnormalities of the median nerve as detected by electrodiagnostic tests and the measurement of the cross-sectional area of the nerve by US ($P < 0.05$). A cut-off point of 0.88 mm^2 for the mean cross-sectional area of the median nerve was found to be the upper limit for normal values. It was concluded that High-frequency USG examination of the median nerve and measurement of its cross-sectional area can be strongly considered as useful diagnostic modality for the evaluation of CTS along with nerve conduction studies.[75]

In another Indian study, Aggarwal et al (2020) studied the accuracy of high-resolution ultrasonography in the CTS. It included 50 patients with signs and symptoms suggestive of CTS and 50 individuals as control group. Data comparison between Cross-sectional area of median nerve at the inlet of carpal tunnel and NCS showed that a cut-off of cross-sectional area of 9 mm^2 had high sensitivity, specificity and accuracy in diagnosing CTS, respectively 95%, 100% and 97%.In control group, cross-sectional area of the median nerve ranged between 5 and 7.3 mm^2, whereas in the symptomatic group it varied from 8.4 to 16.5 mm^2.It was concluded that Ultrasonographic examination gave similar results to NCS in establishing diagnosis of CTS and could be used as a reliable screening modality.[76]

MATERIALS AND METHODS

A prospective study in all clinically diagnosed cases of CTS, referred for ultrasound assessment of median nerve to the Department of Radiodiagnosis at DMCH Ludhiana, was conducted over a period of one year on LOGIQ E9 or Phillips IU22 machine using a 6-15 Mhz linear probe. Written informed consent was taken from each patient in his/her vernacular language before making him/her part of the study and relevant history was elicited from each patient. An equal number of healthy volunteer age-matched controls were also imaged on ultrasound and all the relevant sonographic parameters were measured. The subjects in the control group were either healthy relatives accompanying the patients during their visit to the hospital or from hospital staff. They were subjected to detailed history to verify their normality.

SOURCE OF DATA

The study was conducted on all patients of any age group with clinical diagnosis of Carpal tunnel Syndrome referred from indoor or outdoor patient department to the department of Radiodiagnosis, DMCH for ultrasound evaluation.

METHOD OF COLLECTION OF DATA

INCLUSION CRITERIA

Patient with clinical diagnosis of Carpal Tunnel Syndrome.

EXCLUSION CRITERIA-

1) Patients with fracture of carpal bones or carpo-metacarpal dislocations.

2) Patients with distorted anatomy at wrist joint and those who underwent surgery around the wrist.

3) Patients with Bifid median nerve/ any other normal anatomical variation.

4) Patients who didn’t consent to be part of the study.

DURATION OF STUDY

The study was conducted over a period of one year from December 2018 to December 2019.

SONOGRAPHIC EVALUATION

The median nerve was imaged at the wrist joint in transverse and longitudinal planes using high-resolution real-time sonography. For the purpose of sonographic examination, individuals were positioned with forearm supine, elbow semi-flexed, and the fingers and wrist in a neutral position. Transverse and longitudinal images of the median nerve were obtained at two levels: at the carpal tunnel inlet (level of scaphoid and pisiform) and at the carpal tunnel outlet (trapezium and hook of hamate level). Parameters evaluated on ultrasonography included echogenicity of the nerve, cross sectional areas at inlet and outlet, flattening of median nerve and bowing of palmar retinaculum (>4 mm at outlet).

Asymptomatic wrist of the same patient and healthy volunteer age matched controls were also imaged on ultrasound and all the relevant parameters were measured and recorded.

ELECTRODIAGNOSTIC EVALUATION

Electrodiagnostic studies were performed by the Department of Neurology at DMCH Ludhiana, for all subjects included in the study according to the protocol put forth by the American Association of Electrodiagnostic Medicine recommendations. The machine used for the study was Nihon Coden (Model number-MEB-9400K). All the nerve conduction studies were done in the same room and in similar temperature conditions. Standard tests for Median sensory and motor conductions were done looking at the distal latency, conduction velocity across the wrist and amplitude.

The criteria for diagnosis of CTS were –

-Distal sensory latency recorded from the index finger (antidromic stimulation) using ring electrodes >3.6 ms.

-Distal motor latency of Median nerve recorded from the abductor pollicis brevis and stimulating 3 cms proximal to the distal crease of the wrist if exceeds 4.2 ms.

When standard tests mentioned above yielded normal results, a comparative median/ ulnar studies were done. -Difference between distal motor latency of Median and Ulnar nerves > 1.1ms.

-Difference between distal sensory latency of median and Ulnar nerves > 0.2ms.

F wave was done for all patients.

STATISTICAL ANALYSIS: Data was described in terms of range; mean ±standard deviation (± SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. Sensitivity, specificity, positive and negative predictive values and accuracy of each method and its confidence interval (95% CI) was also determined as appropriate, besides the Youden index (probability of correct classification) , determining the area under the ROC curve and calculation of optimal cut off values (of cross-sectional areas). The co-relation of the Cross sectional areas and nerve conduction study parameters was also done with calculation of pearson coefficient. A probability value (*p* value) less than 0.05 was considered statistically significant. All statistical calculations were done using SPSS (Statistical Package for the Social Science) SPSS 21 version statistical program for Microsoft Windows.

OBSERVATION AND RESULTS

This study was conducted in Dayanand Medical College and Hospital, Ludhiana from December 2018 to December 2019. A total of 90 patients who presented with clinical suspicion of carpal tunnel syndrome underwent high resolution ultrasonography and nerve conduction studies in Dayanand Medical College and Hospital, Ludhiana. Out of these 90 patients, 17 patients met the exclusion criteria and were excluded from the study. Similar numbers of age matched controls were also evaluated by high resolution ultrasonography and relevant parameters were measured.

Table 1: Sex distribution among cases

SEX	No. of cases	Percentage
F	57	78.1%
M	16	21.9%
Total	73	100.0%

In present study, 16 cases were males and 57 cases were females. The female to male ratio was 3.6:1.

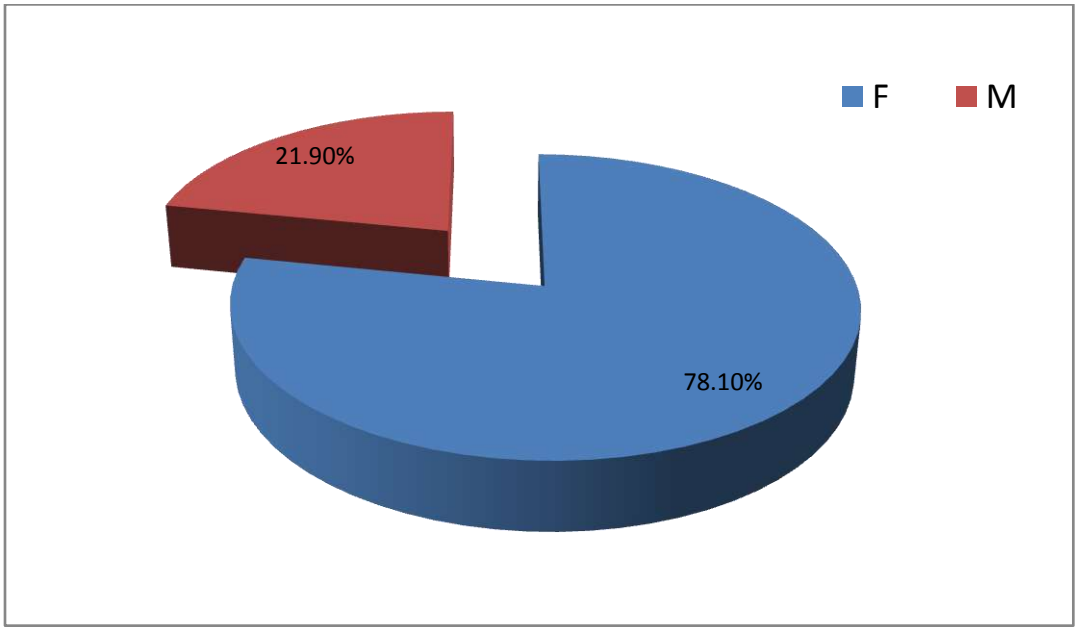

Fig 9: Sex distribution among cases

Table 2: Sex distribution among controls

SEX	No. of cases	Percentage
F	50	68.5%
M	23	31.5%
Total	73	100.0%

Amongst the control group, 23 cases were male and 50 were female. The female to male ratio was 2.2:1.

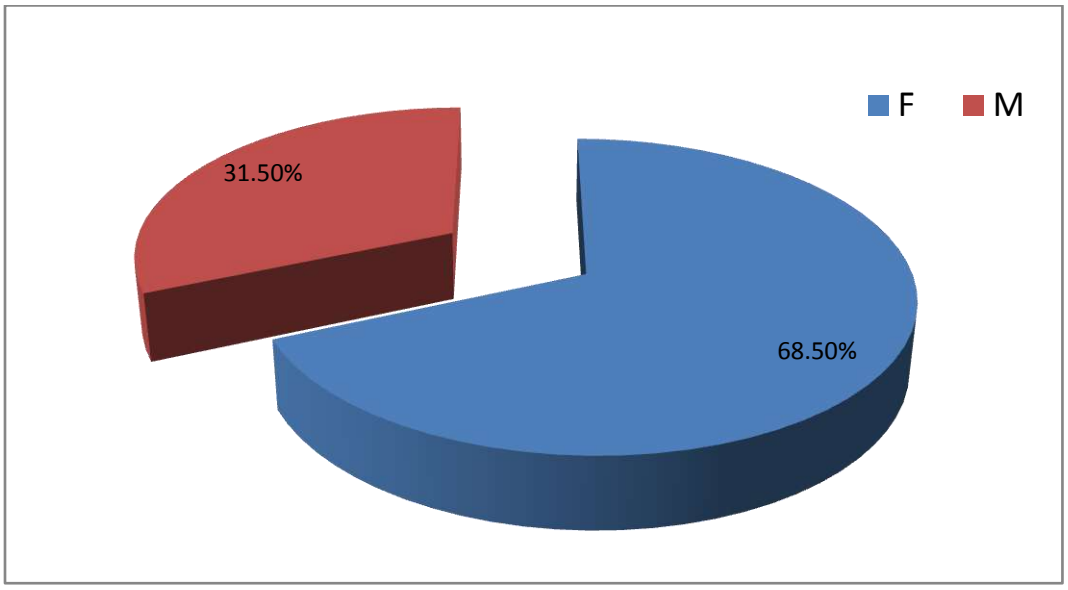

Fig 10: Sex distribution among controls

Table 3: Age distribution among cases

AGE	No. of cases	Percentage
< 30	6	8.2%
31-40	20	27.4%
41-50	27	37.0%
51-60	15	20.5%
> 60	5	6.8%
Total	73	100.0%

The age distribution in the patient population was between 23-79 years with a mean age of 45.34±11.18 years.

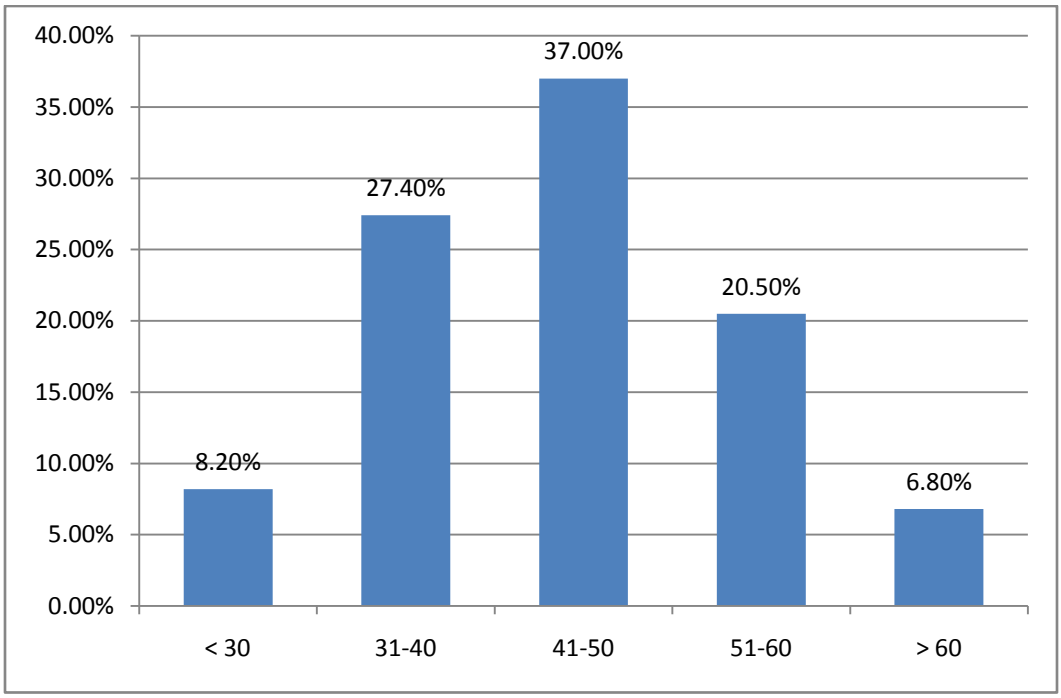

Fig 11: Age distribution among cases

Table 4: Age distribution among controls

AGE	No. of controls	Percentage
< 30	11	15.1%
31-40	20	27.4%
41-50	22	30.1%
51-60	14	19.2%
> 60	6	8.2%
Total	73	100.0%

Among the control group the age distribution was between 23-79 years with a mean age of 44.07±12.34 years.

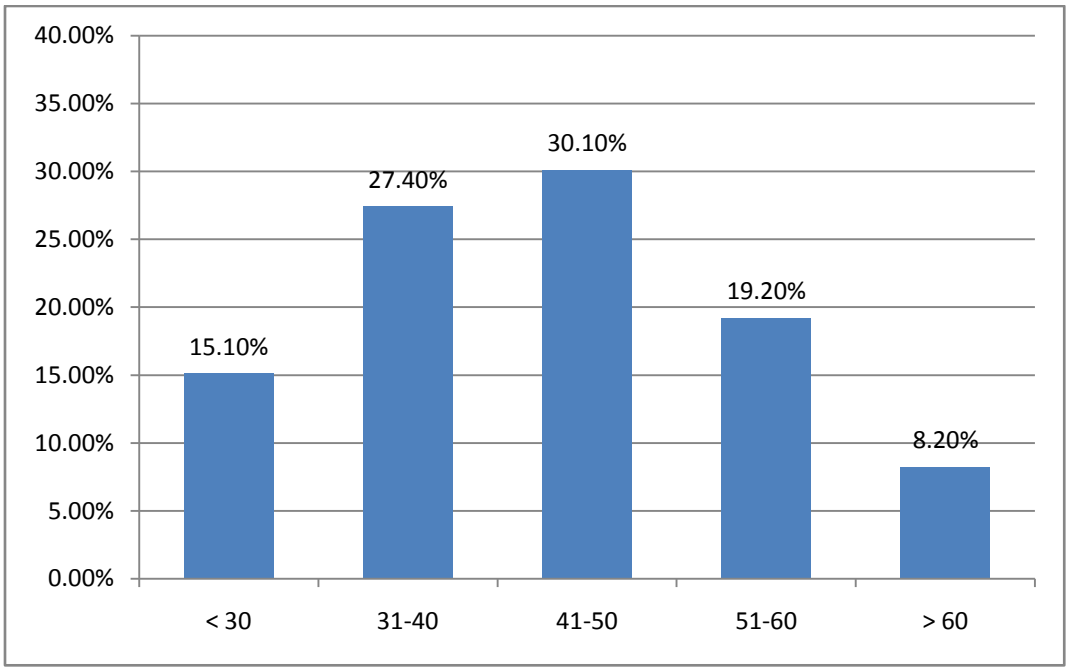

Fig 12: Age distribution among controls

Table 5: Body Mass Index (BMI) distribution among cases

BMI(kg/m²)	No. of cases	Percentage	Category
< 18.5	1	1.4%	Underweight
18.5-24.9	50	68.5%	Normal
25.1-29.9	17	23.3%	Overweight
> 30	5	6.8%	Obese
Total	73	100.0%	

The BMI among the cases ranged from 16.8 to 40.3 kg/m² with a mean value of 24.13±3.58 kg/m².

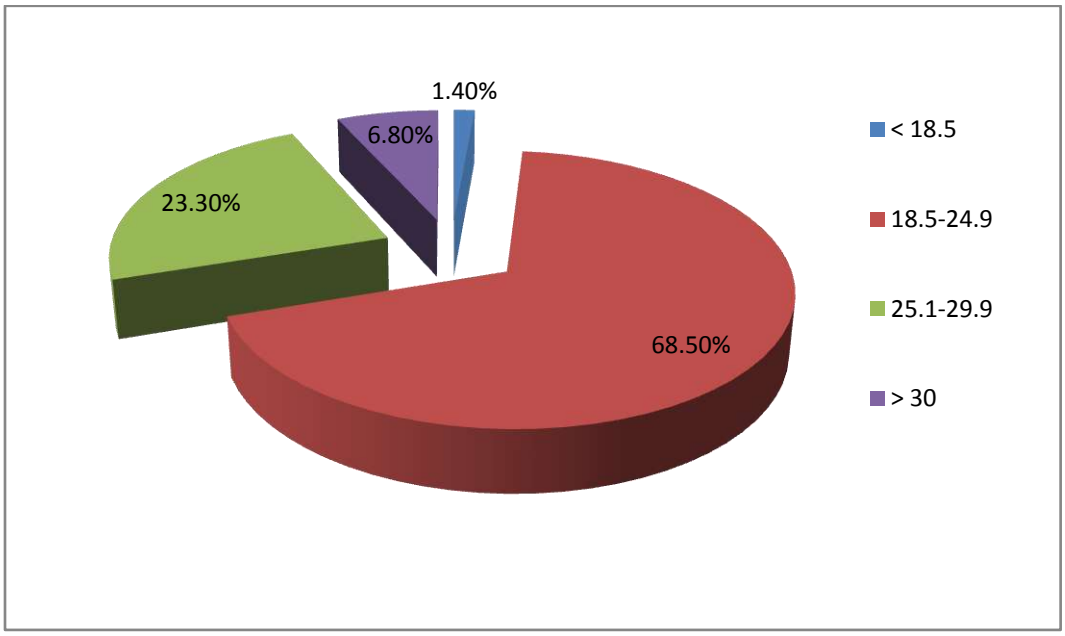

Fig 13: BMI distribution among cases

Table 6: Body Mass Index (BMI) distribution among controls

BMI(kg/m²)	No. of cases	Percentage	Category
< 18.5	3	4.1%	Underweight
18.5-24.9	64	87.7%	Normal
25.1-29.9	6	8.2%	Overweight
> 30	0	0.0%	Obese
Total	73	100.0%	

The BMI among the controls ranged from 18 to 28 kg/m² with mean value of 22.32±1.89 kg/m².

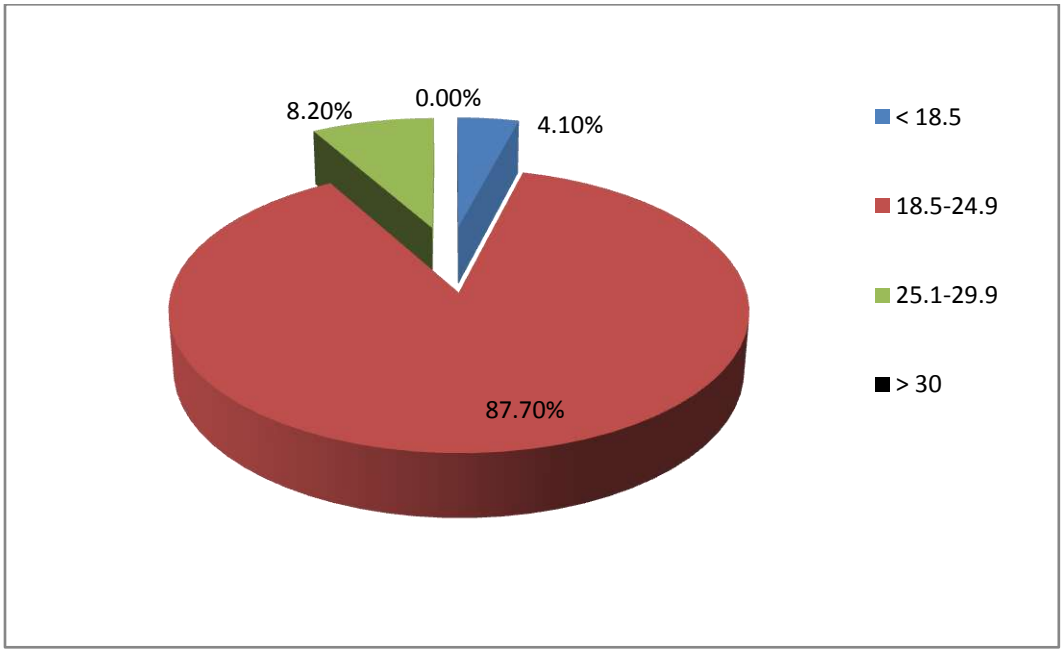

Fig 14: BMI distribution among controls

Table 7: Distribution of bifid nerve among cases

Bifid Nerve	No. of cases	Percentage
Yes	17	18.89%
No	73	81.11%
Total	90	100.0%

In the present study, 17 out of 90 patients had bifid nerve and were excluded from the cases.

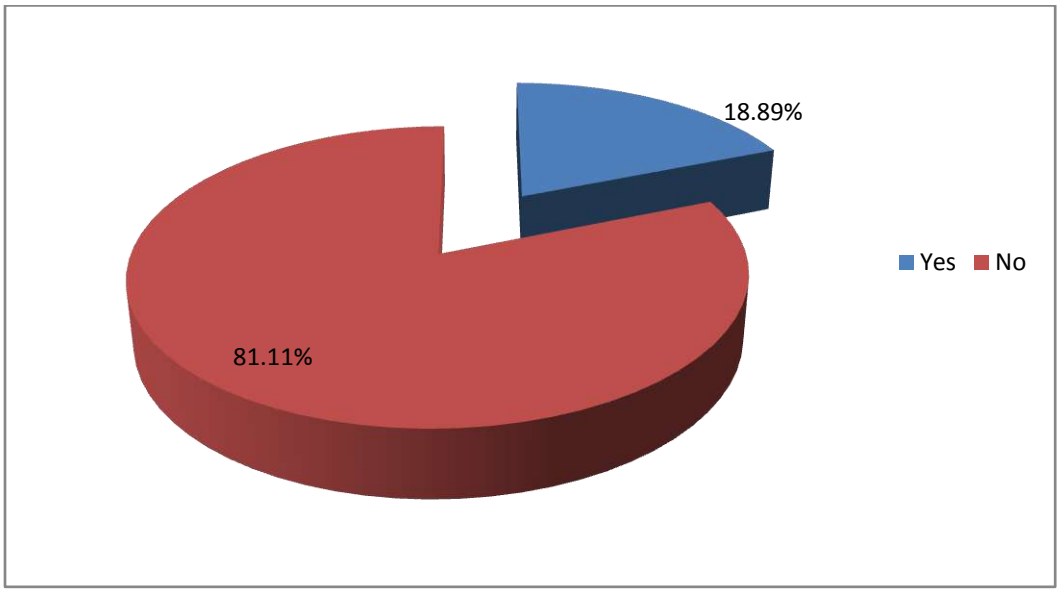

Fig 15: Distribution of bifid nerve among cases

Table 8: Distribution of bifid nerve among controls

Bifid Nerve	No. of controls	Percentage
Yes	2	2.67%
No	73	97.33%
Total	75	100.0%

In the present study, 2 out of 75 patients had bifid nerve and were excluded from the controls.

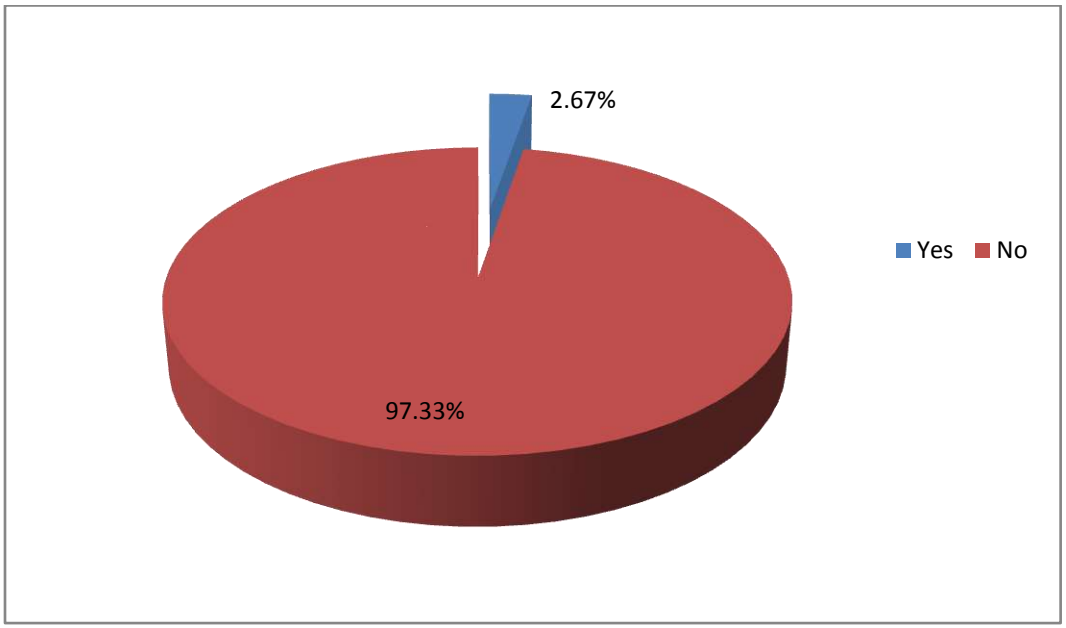

Fig 16: Distribution of bifid nerve among controls

Table 9: Distribution of persistent median artery among cases

Persistent Median artery	No. of cases	Percentage
Yes	2	2.22%
No	88	97.78%
Total	90	100.0%

In the present study, 2 out of 90 patients had persistent median artery as an anatomical variant.

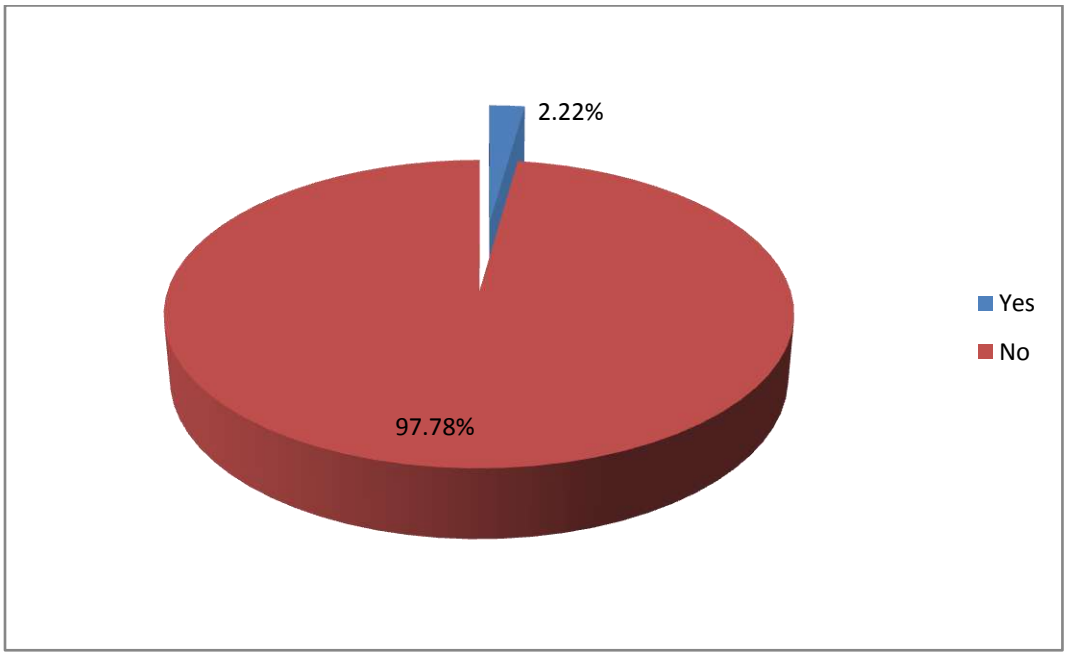

Fig 17: Distribution of persistent median artery among cases

Table 10: Distribution of persistent median artery among controls

Persistent Median artery	No. of controls	Percentage
Yes	0	0%
No	75	100%
Total	75	100.0%

In the present study, none of the controls had persistent median artery as an anatomical variant.

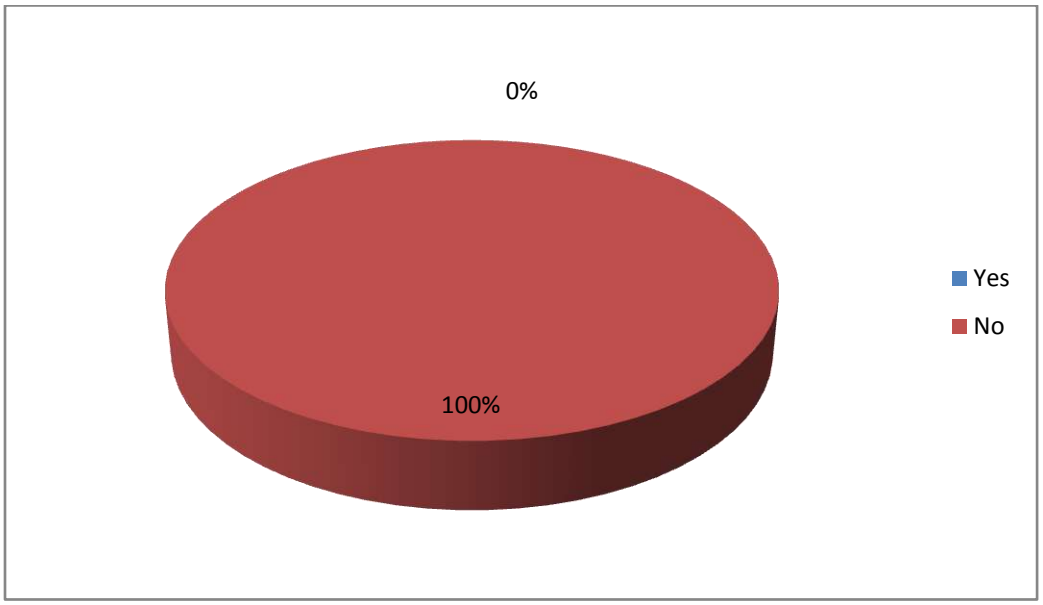

Fig 18: Distribution of persistent median artery among controls

Table 11: Presenting complaints

Symptoms	No. of cases	Percentage
Numbness of hands	48	65.7%
Pain in hands	14	19.2%
Both Pain and numbness	11	15.1%
Total	73	100.0%

Of the total 73 patients, 48 had numbness of hands as a presenting symptom, 14 presented with pain in hands and 11 presented with both pain and numbness in hands.

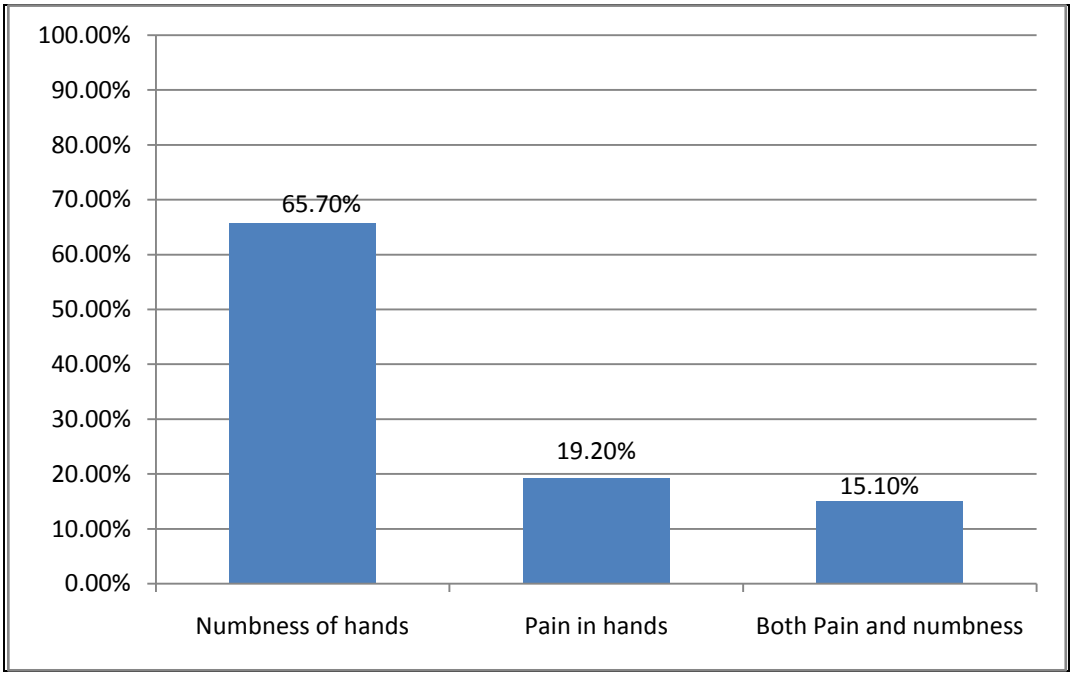

Fig 19: Distribution of presenting complaints

Table 12: Distribution of laterality of symptoms in cases

Laterality of Symptoms	No. of cases	Percentage
Bilateral (B/l)	50	68.5%
Left	13	17.8%
Right	10	13.7%
Total	73	100.0%

Of the total number of 73 patients, 50 presented with bilateral symptoms, 23 had symptoms of unilateral disease, of which 10 patients had right handed symptoms and 13 patients were found to have left handed symptoms.

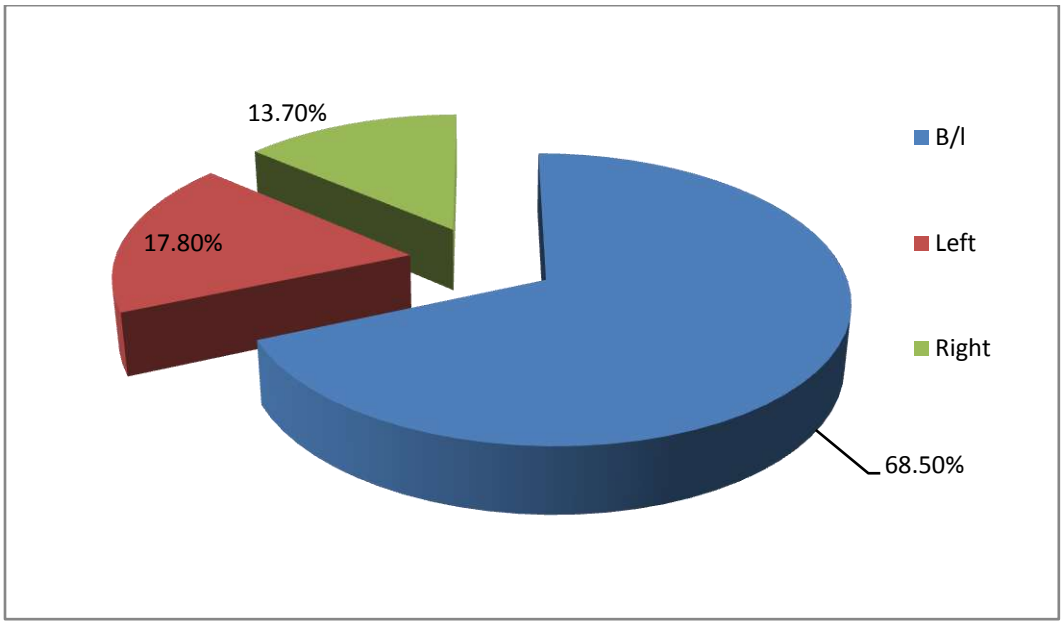

Fig 20 : Distribution of laterality of symptoms in cases

Table 13: Distribution of clinical tests among cases: Tinel test

TINEL TEST	No. of hands	Percentage
Positive	56	38.36%
Negative	90	61.64%
Total hands	146	100%

Of the total 146 wrists examined, Tinel test was positive in 56 hands.

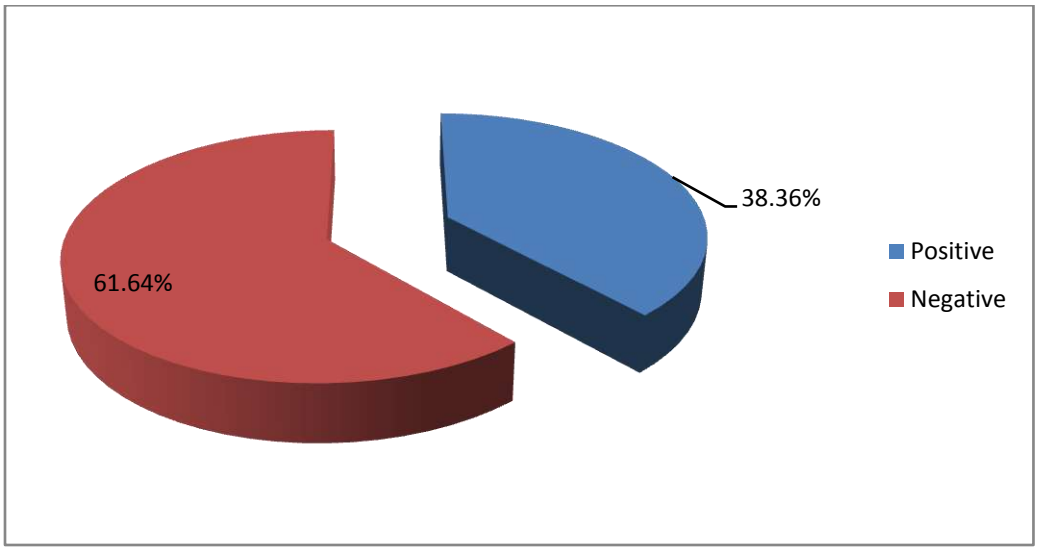

Fig 21: Distribution of Tinel test among cases

Table 14: Sensitivity and Specificity of Tinel test compared to NCS

		NCS		Total Hands
		Positive	**Negative**	
TINEL TEST	**Positive**	41	15	56
	Negative	30	60	90
Total hands		71	75	146

The Sensitivity and Specificity of Tinel test as compared to NCS is 57.75% and 80.00% respectively.

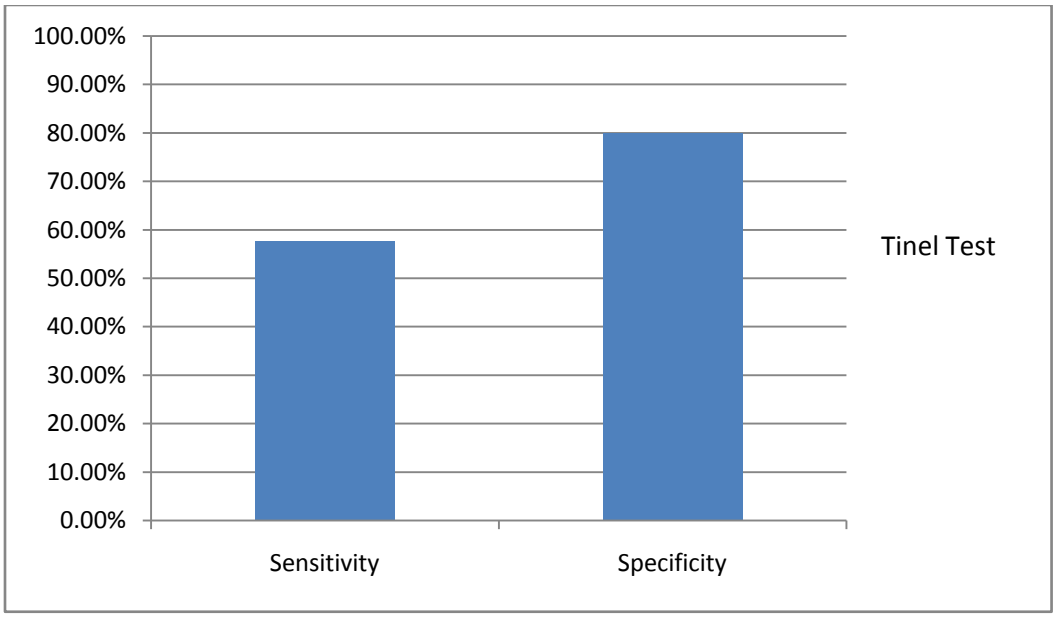

Fig 22: Sensitivity and Specificity of Tinel test compared to NCS.

Table 15: Distribution of clinical tests among cases: Phalen's test

PHALEN TEST	No. of cases	Percentage
Positive	57	39.04%
Negative	89	60.96%
Total hands	146	100%

Of the total 146 wrists examined, Phalen's test was positive in 57 hands.

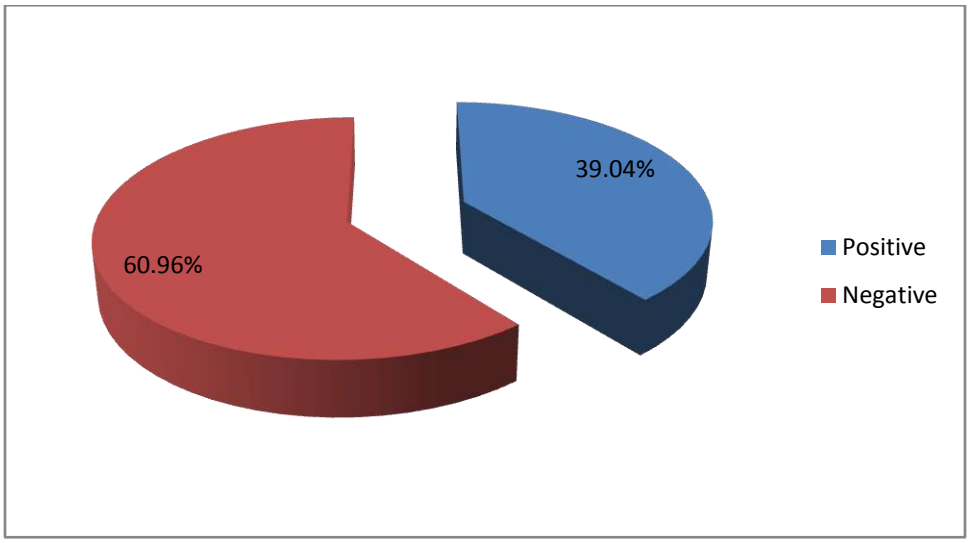

Fig 23: Distribution of Phalen's test among cases

Table 16: Sensitivity and Specificity of Phalen's test compared to NCS.

		NCS		Total Hands
		Positive	**Negative**	
PHALEN'sTEST	**Positive**	43	14	57
	Negative	28	61	89
Total hands		71	75	146

The Sensitivity and Specificity of Phalen's test as compared to NCS is 60.56% and 81.33% respectively.

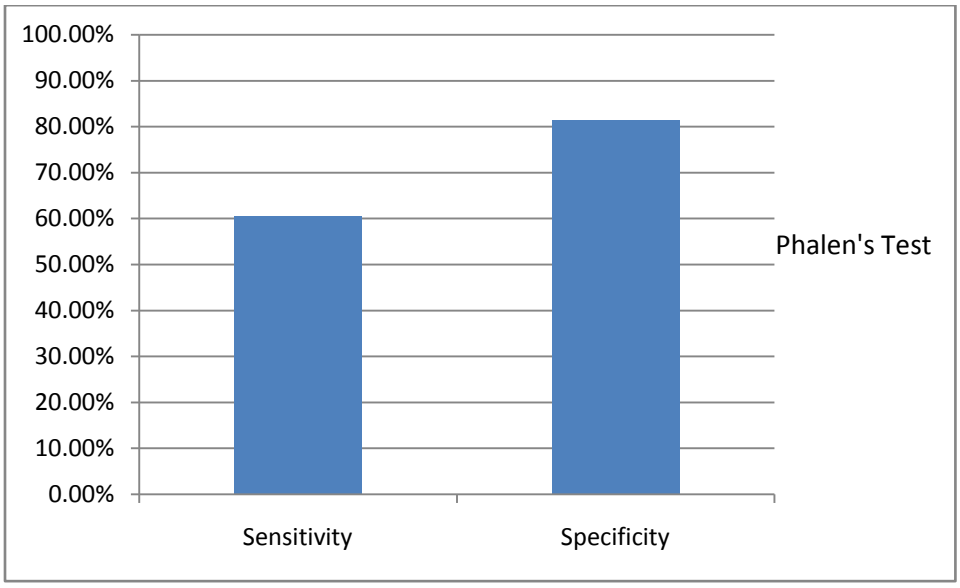

Fig 24: Sensitivity and Specificity of Phalen's test compared to NCS

Table 17: Comparison of the cross sectional areas at level of inlet and outlet between CTS patients and controls.

	Cases		Control		t	p-value
	Mean CSA (cm^2)	SD	Mean CSA (cm^2)	SD		
Inlet	0.09	0.03	0.07	0.01	7.823	<0.001
Outlet	0.09	0.03	0.07	0.01	7.156	<0.001

The mean CSA at both inlet and outlet was 0.09 ± 0.03 cm^2 in the cases, while in control group the mean CSA at both inlet and outlet was 0.07± 0.01 cm^2.(p value <0.001)

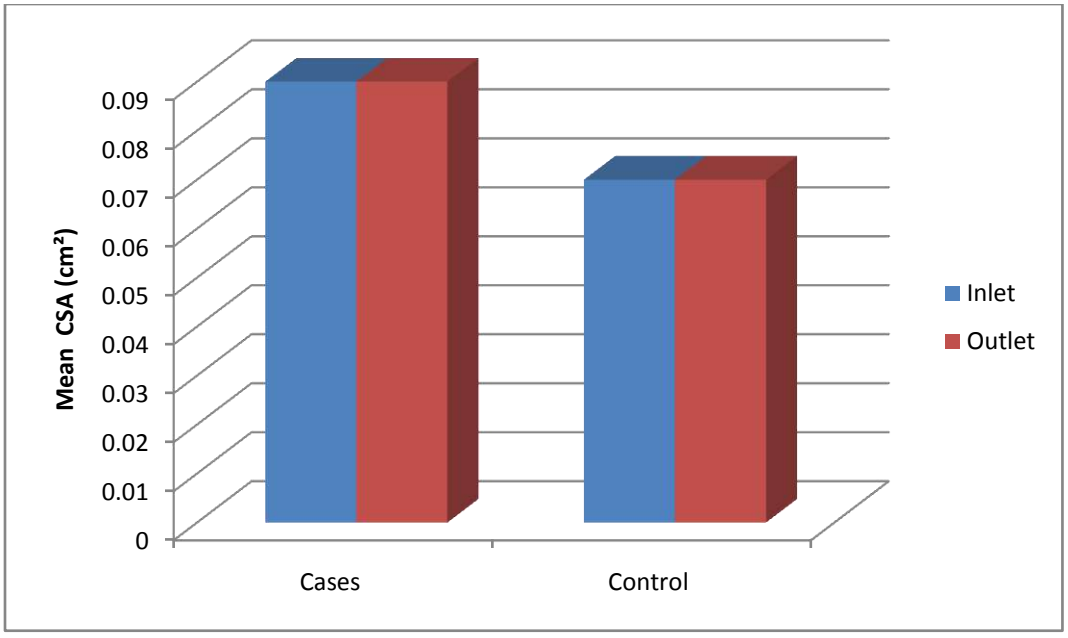

Fig 25: Mean Cross sectional area among cases and controls at inlet and outlet.

Receiver Operator curves (ROC) calculated at inlet and outlet.

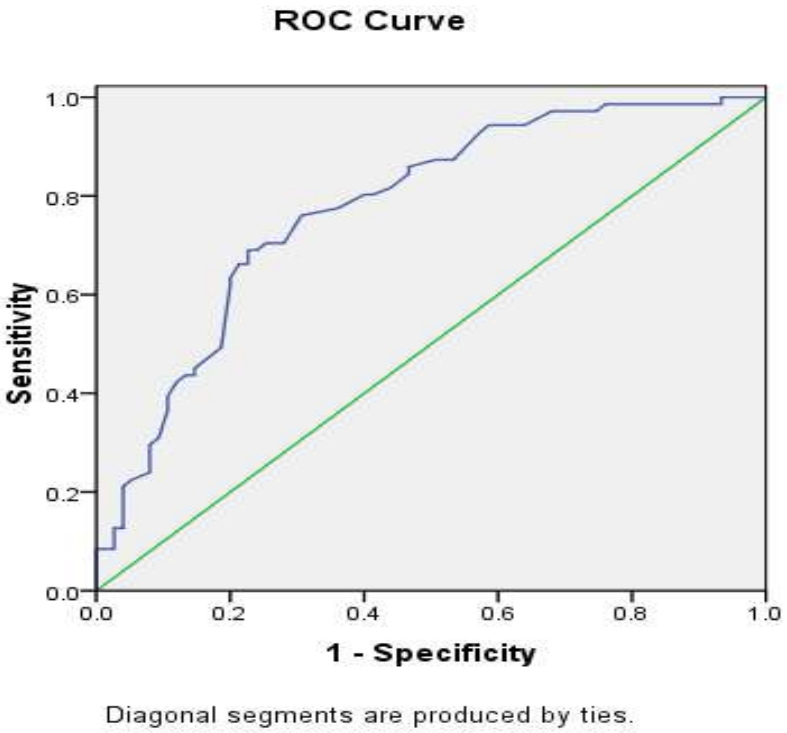

Fig 26: ROC at inlet

Table 18: Area Under the Receiver Operator Curve at Inlet

Test Result Variable :Cross Sectional Area(cm^2) Inlet

Area	Standard Error	p-value	Asymptotic 95% ConfidenceInterval	
			Lower Bound	Upper Bound
0.777	0.038	0.000	0.701	0.852

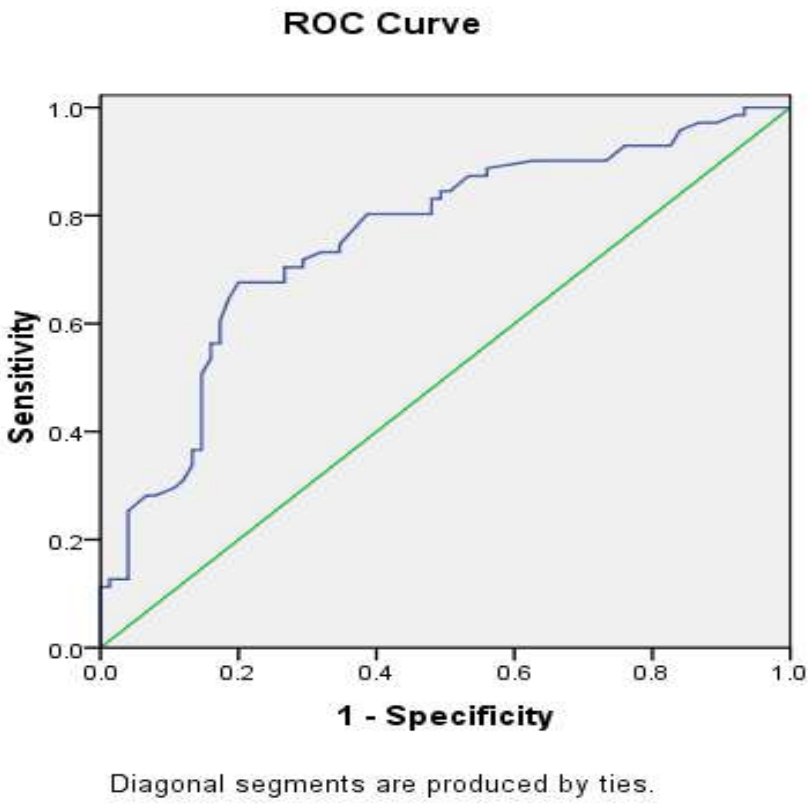

Fig 27: ROC curve at outlet

Table19: Area Under the Receiver Operator Curve at Outlet

Test Result Variable: Outlet

Area	Standard Error	Asymptotic Significance	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
0.758	0.040	0.000	0.679	0.837

Multiple values were obtained on analysis of data for the best cut off value. Based on the ROC, the values with the best sensitivity and specificity at the level of inlet and outlet were taken using Youden index, given in the table below.

Table 20: Sensitivity and specificity for the cut offs of the cross sectional areas of the median nerve at the level of inlet and at the outlet.

Level	Cut off (cm^2)	Sensitivity	Specificity
Inlet	0.09 cm^2	66%	79%
Outlet	0.09 cm^2	68%	80%

At both inlet and outlet, a cut off of 0.09 cm^2 yielded maximum sensitivity and specificity. The sensitivity and specificity values at inlet was 66 % and 79 % respectively, while at outlet, these were 68 % and 80 % respectively.

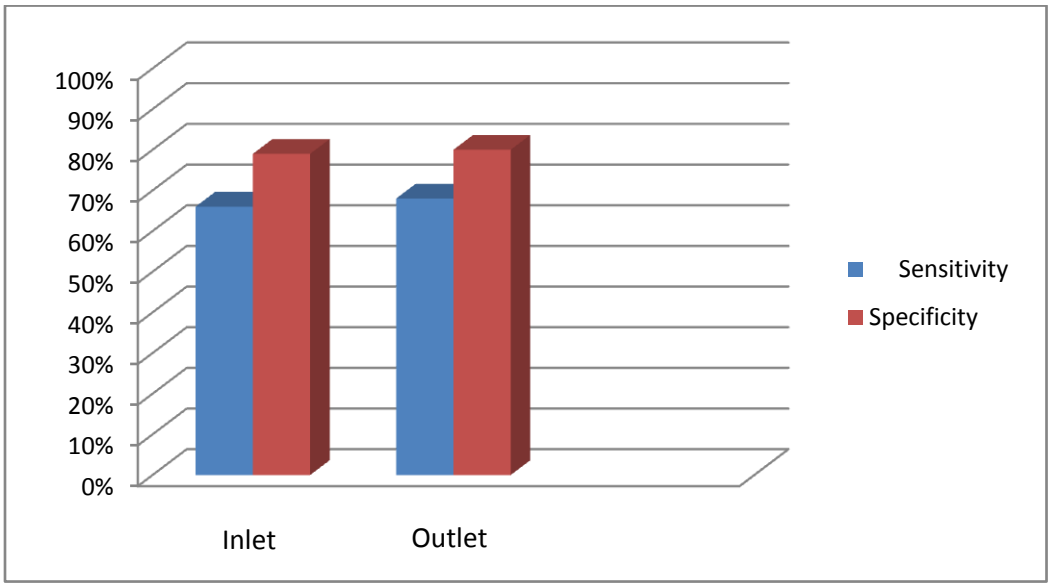

Fig 28: Sensitivity and specificity for the cut offs (0.09 cm^2) of the cross sectional areas of the median nerve at the level of inlet and at the outlet.

Table 21: Sensitivity, Specificity, Positive predictive value (PPV) and Negative predictive value (NPV) of the cross sectional area of the median nerve at the inlet of the carpal tunnel as compared to NCS.

Level	Cut-off (cm^2)	Sensitivity	Specificity	PPV	NPV
Inlet	0.09 cm^2	66.00%	79.00%	74.60%	71.08%
Confidence Interval (95% CI)		53.99% to 77.77 %	67.68% to 87.2%	64.85% to 82.39%	63.49% to 77.66%

The respective Sensitivity, Specificity, Positive predictive value and Negative predictive value of ultrasound to diagnose CTS by the increase in the cross sectional area at the level of inlet of the carpal tunnel compared to NCS is 66.00%,79.00%,74.60% and 71.08%.

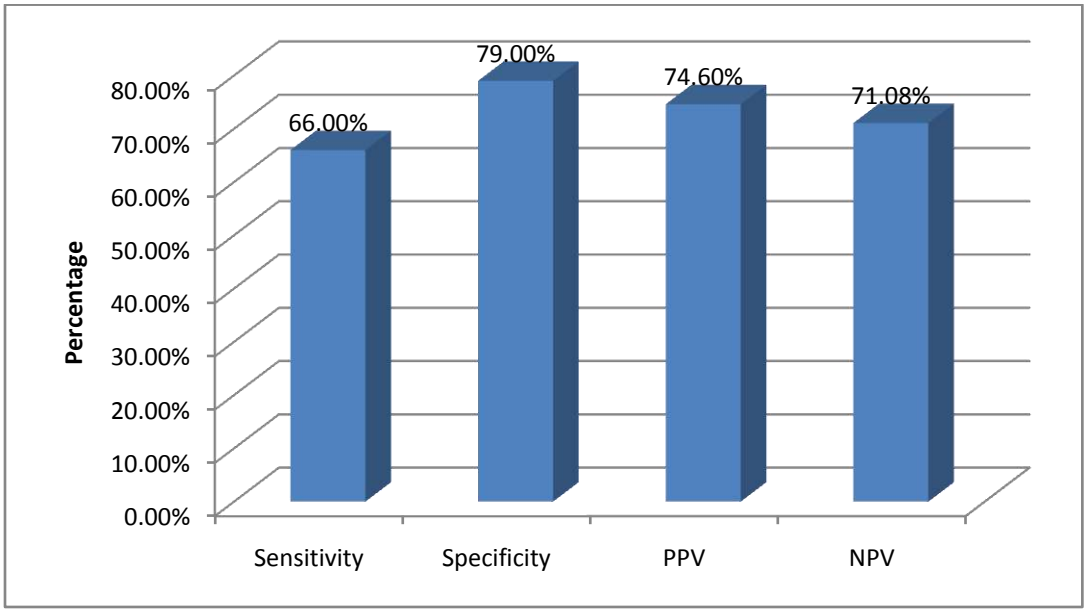

Fig 29: Sensitivity, Specificity, Positive predictive value (PPV) and Negative predictive value (NPV) of the cross sectional area of the median nerve at the inlet of the carpal tunnel as compared to NCS.

Table 22: Sensitivity, Specificity, Positive predictive value (PPV) and Negative predictive value (NPV) of the cross sectional area of the median nerve at the outlet of the carpal tunnel as compared to NCS.

Level	Cut off (cm^2)	Sensitivity	Specificity	PPV	NPV
Inlet	0.09 cm^2	68.00%	80.00%	70.59%	71.60%
Confidence Interval (95% CI)		55.45% to 78.24%	63.21%to 83.58%	61.41% to 78.35%	63.75%to 78.34%

The respective Sensitivity, Specificity, Positive predictive value and Negative predictive value of ultrasound to diagnose CTS by the increase in the cross sectional area at the level of outlet of the carpal tunnel compared to NCS is 68.00%,80.00%,74.36% and 71.60%.

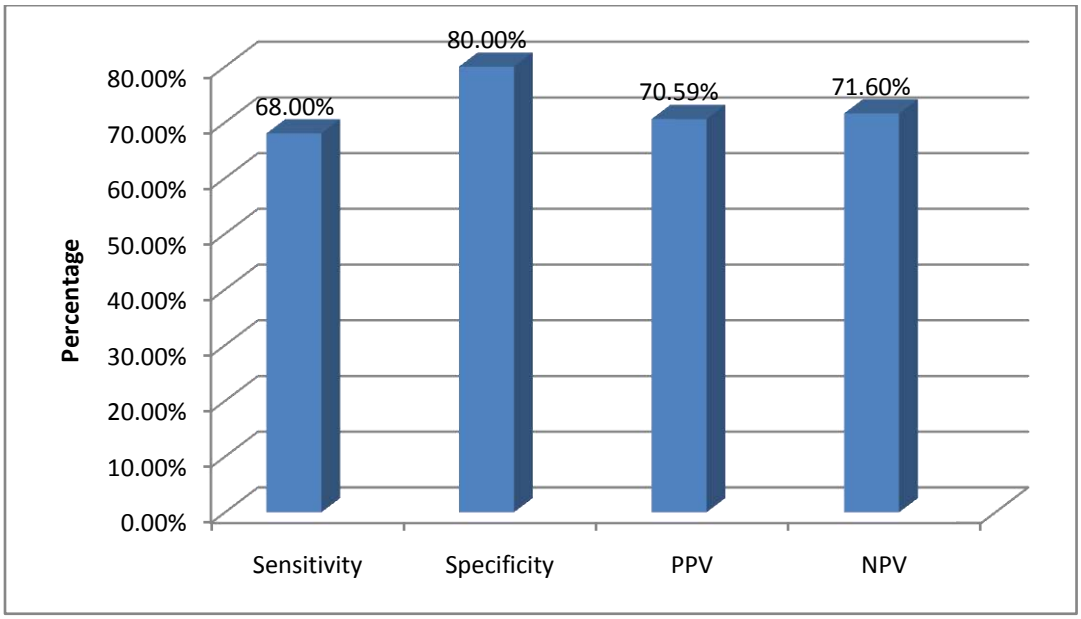

Fig 30: Sensitivity, Specificity, Positive predictive value (PPV) and Negative predictive value (NPV) of the cross sectional area of the median nerve at the outlet of the carpal tunnel as compared to NCS.

Table 23:Distribution of Nerve Hypoechogenicity among cases

Nerve Hypoechogenicity	No. of hands	Percentage
Present	43	29.45%
Absent	103	70.55%
Total hands	146	100%

Out of 146 hands examined, Nerve Hypoechogenicity was observed in 43 hands.

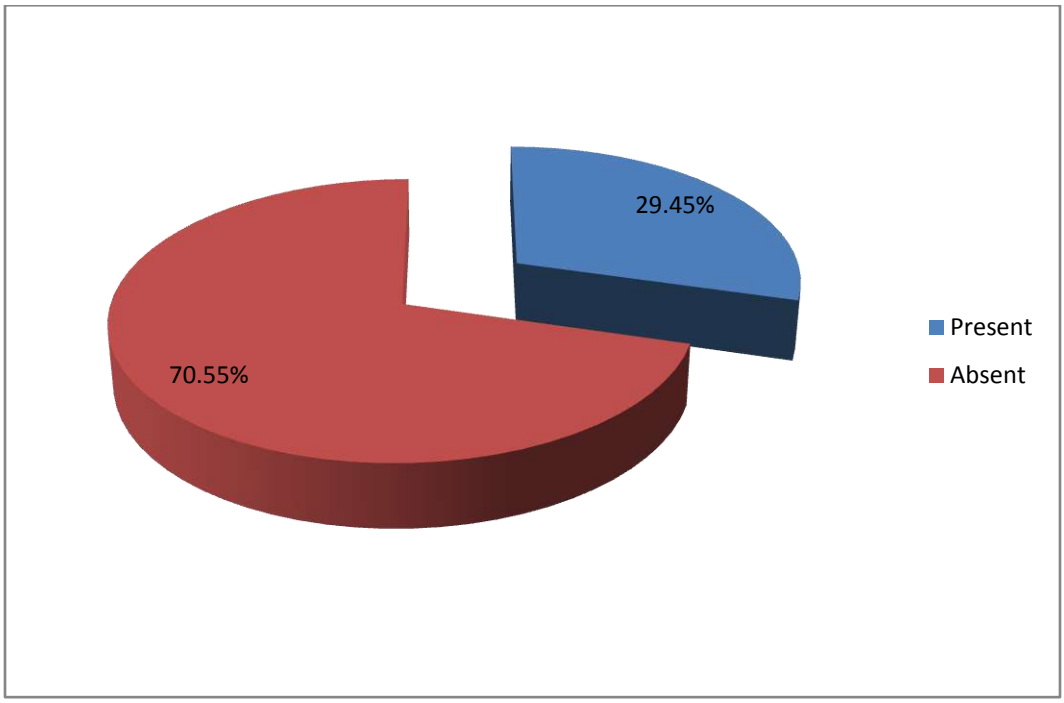

Fig 31: Distribution of Nerve Hypoechogenicity among Cases

Table 24: Sensitivity and Specificity of Nerve Hypoechogenicity compared to NCS

		NCS		Total Hands
		Positive	Negative	
Nerve Hypoechogenicity	Positive	40	3	43
	Negative	31	72	103
Total hands		71	75	146

The Sensitivity and Specificity of Nerve Hypoechogenicity as compared to NCS is 56.34% and 96.00% respectively.

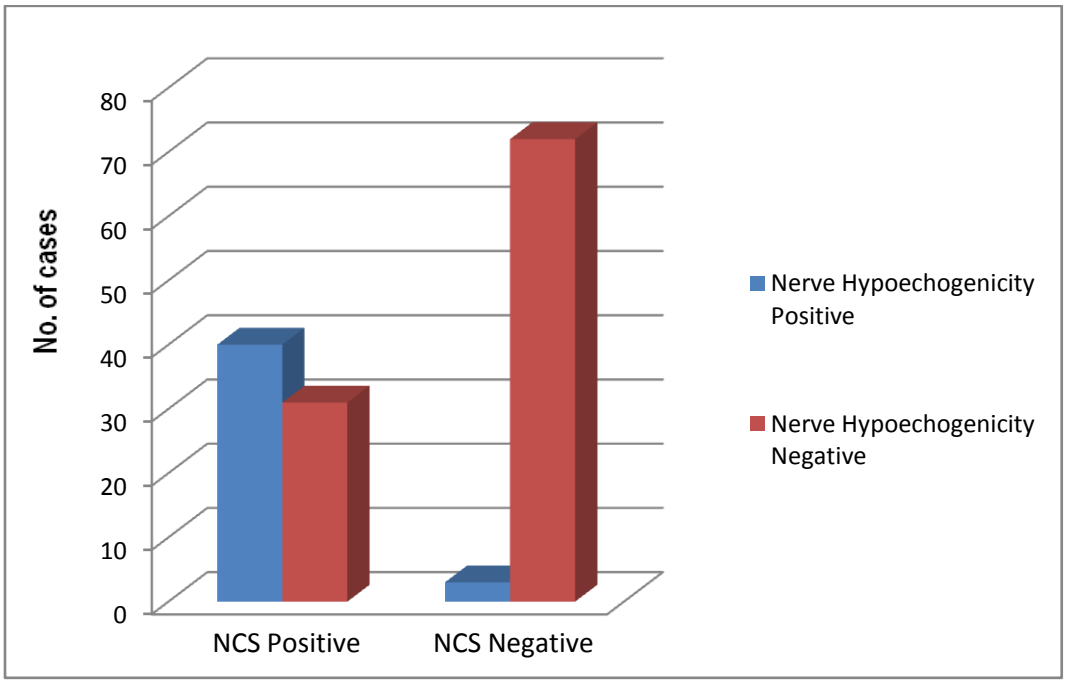

Fig 32: Distribution of Nerve Hypoechogenicity compared to NCS among cases.

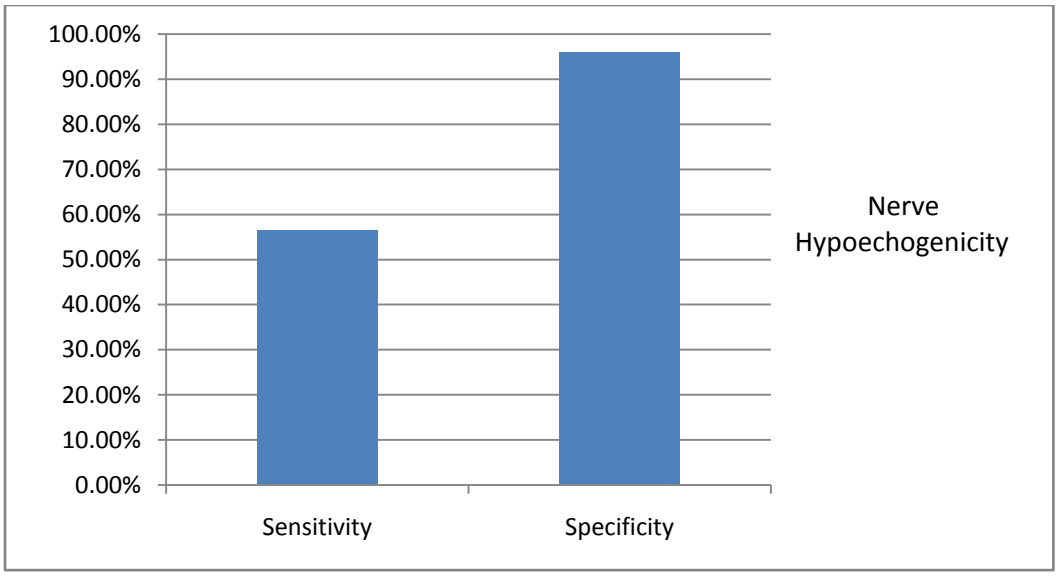

Fig 33: Sensitivity and Specificity of Nerve Hypoechogenicity compared to NCS.

Table 25: Distribution of Flattening of nerve among cases

Nerve Flattening	No. of hands	Percentage
Present	40	27.40%
Absent	106	72.60%
Total hands	146	100%

Out of 146 hands examined, nerve flattening was observed in 40 hands.

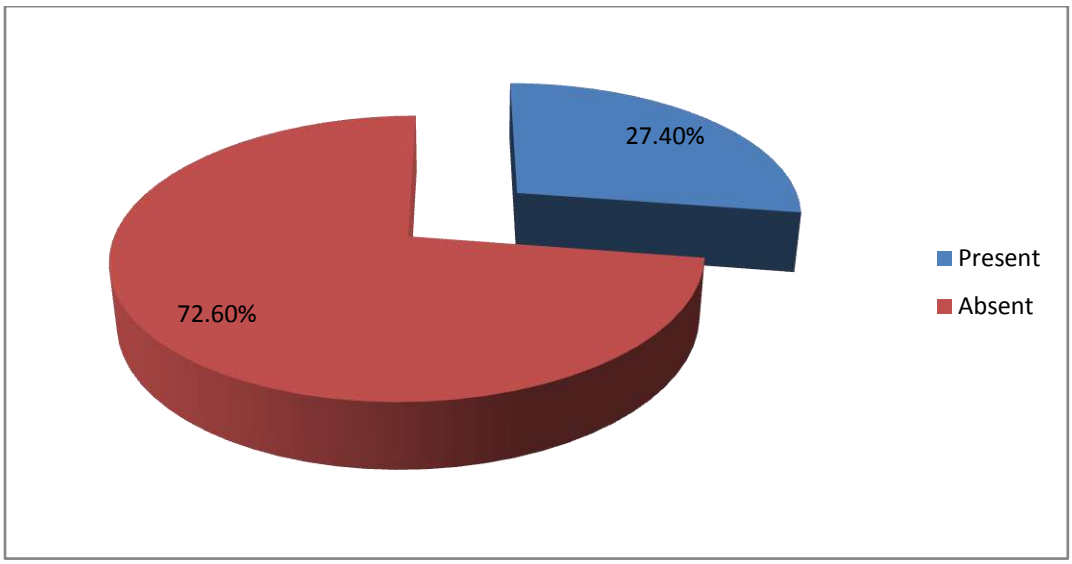

Fig 34: Distribution of Flattening of nerve among cases

Table 26: Sensitivity and Specificity of Flattening of nerve compared to NCS.

		NCS		Total hands
		Positive	Negative	
Flattening of nerve	Positive	36	4	40
	Negative	35	71	106
Total hands		71	75	146

The Sensitivity and Specificity of nerve flattening as compared to NCS studies is 50.70% and 94.67% respectively.

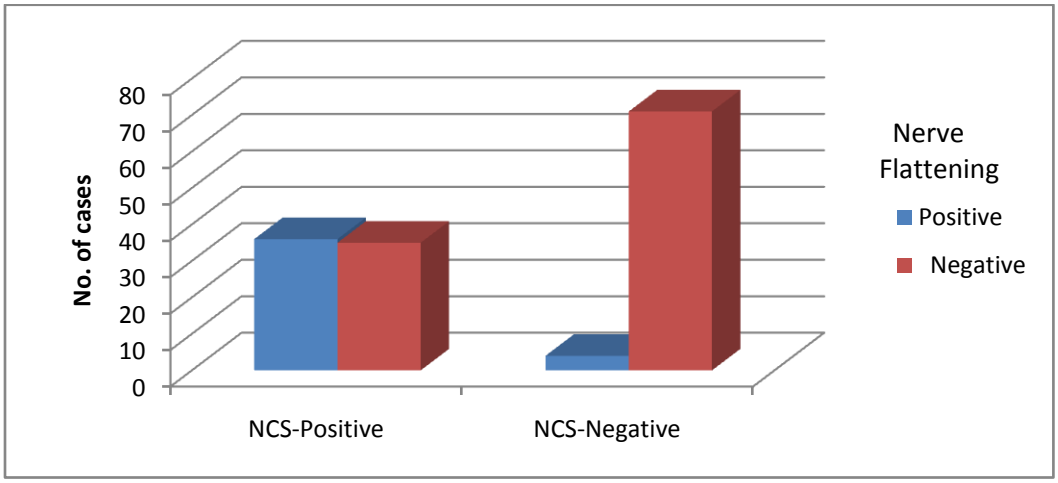

Fig 35: Distribution of Flattening of nerve compared to NCS among cases

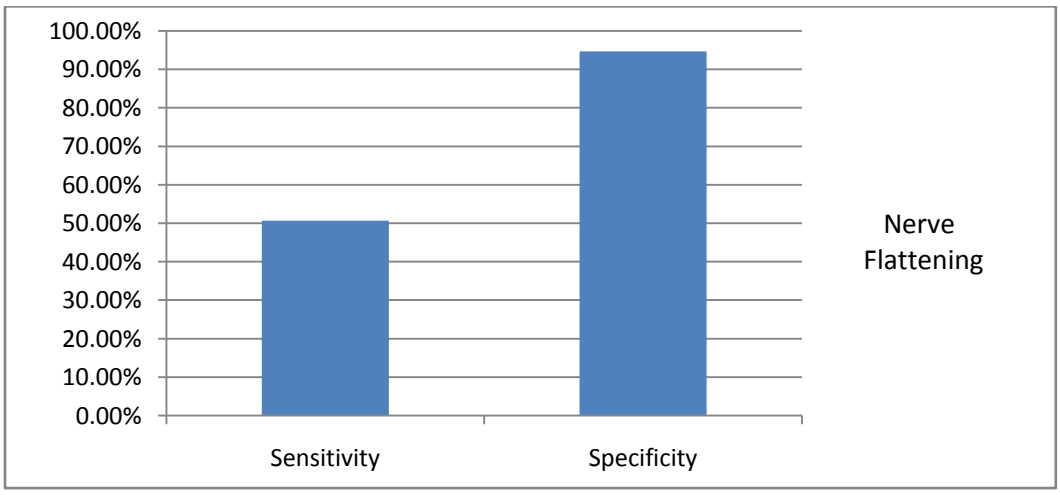

Fig 36: Sensitivity and Specificity of Flattening of nerve compared to NCS among cases

Table 27: Distribution of Bowing of Retinaculum among cases

Bowing of Retinaculum	No. of hands	Percentage
Present	26	17.81%
Absent	120	82.19%
Total hands	146	100%

Out of 146 hands examined, Bowing of Retinaculum was observed in 26 hands.

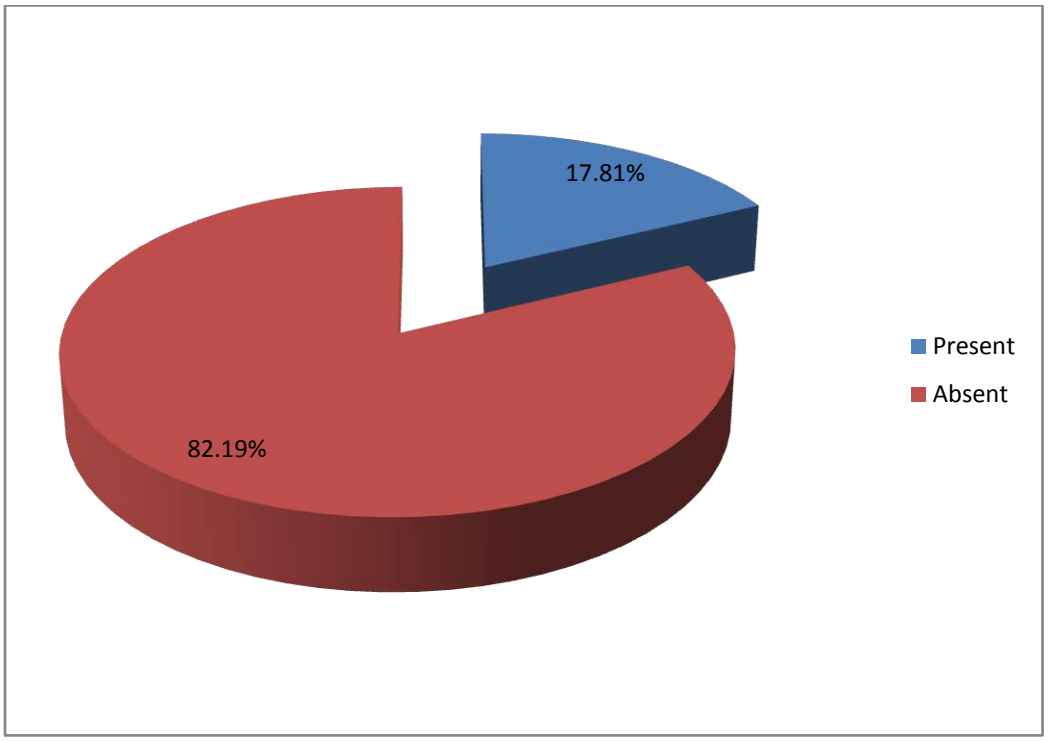

Fig 37: Distribution of Bowing of retinaculum among cases

Table 28: Sensitivity and Specificity of Bowing of Retinaculum compared to NCS

		NCS		Total Hands
		Positive	Negative	
Bowing of retinaculum	**Positive**	18	8	26
	Negative	53	67	120
Total hands		71	75	146

The Sensitivity and Specificity of Bowing of Retinaculum as compared to NCS is 25.35% and 89.33% respectively.

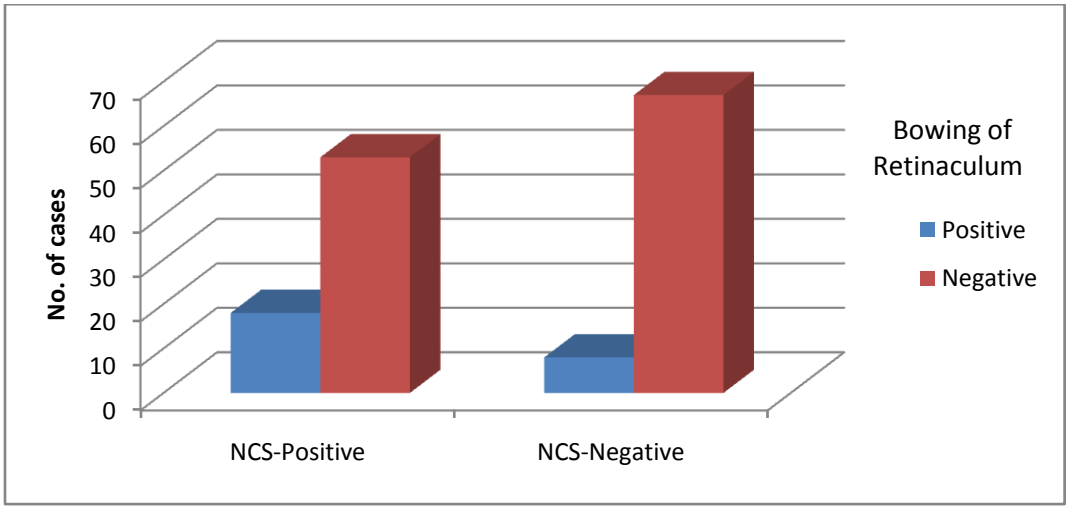

Figure 38: Distribution of Bowing of Retinaculum compared to NCS among cases.

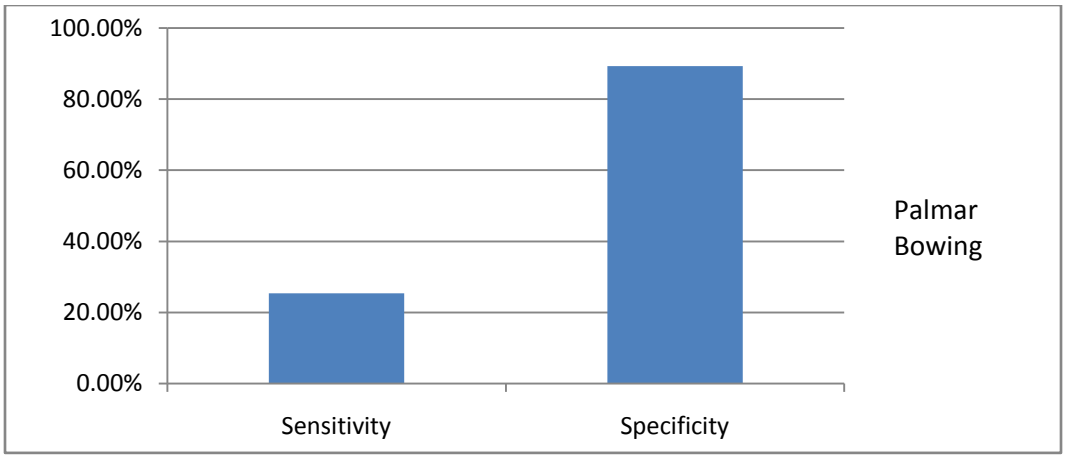

Fig 39: Sensitivity and Specificity of Bowing of Retinaculum compared to NCS

Table 29: Overall Sensitivity, Specificity, Negative predictive value (NPV) and Positive predictive value (PPV) of Ultrasonography compared to NCS in cases.

		NCS Impression		Total hands
		Positive	Negative	
Ultrasound Impression	Positive	50	15	65
	Negative	21	60	81
Total		71	75	146

Ultrasound positive CTS is diagnosed when one value either at the level of inlet or outlet is above the cut off value for that level.

The Overall Sensitivity, Specificity, Positive predictive value (PPV) and Negative predictive value (NPV) of Ultrasonography compared to NCS is 70.42%,80.00%,76.92% and 74.07% respectively.

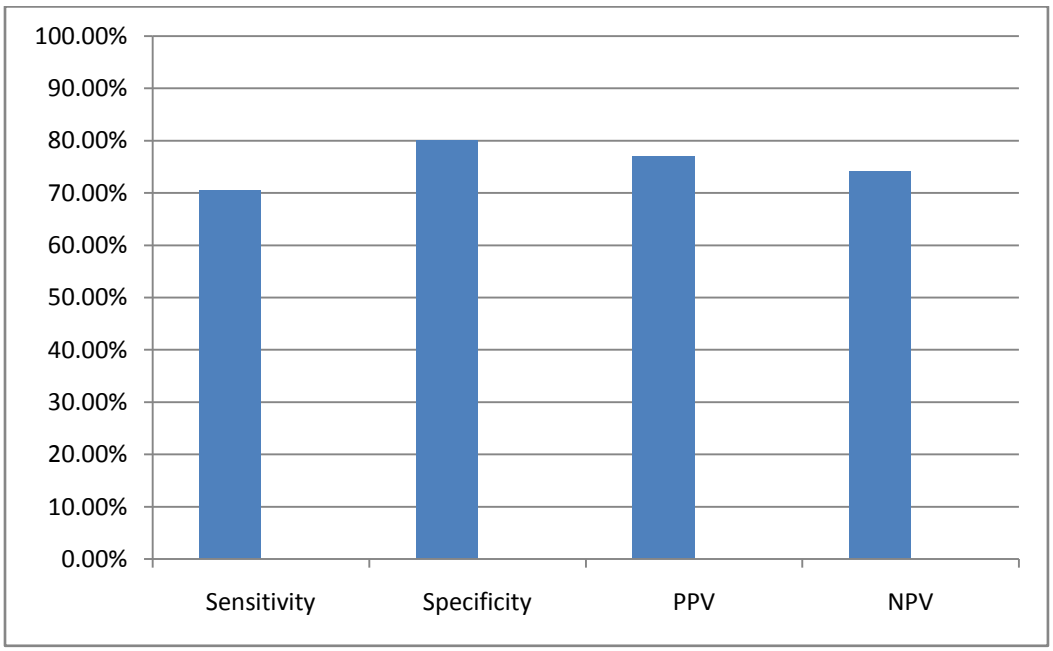

Fig 40: Overall Sensitivity, Specificity, Negative predictive value (NPV) and Positive predictive value (PPV) of Ultrasonography compared to NCS among cases

Table 30: Statistical Correlation of Ultrasonography parameters (Cross sectional areas) with NCS parameters (Distal latency, CMAP, SNAP, Nerve conduction velocity)

		MOTOR Distal latency	MOTOR CMAP	MOTOR NCV	SENSORY Distal latency	SENSORY SNAP	SENSORY NCV
Cross Sectional Area at Inlet	**Pearson Correlation**	0.255	0.012	-0.082	0.336	-0.298	-0.437
	p-value	0.002	0.886	0.328	0.000	0.000	0.000
Cross Sectional Area at Outlet	**Pearson Correlation**	0.274	-0.028	-0.084	0.347	-0.284	-0.418
	p-value	0.001	0.738	0.317	0.000	0.001	0.000

Statistically significant correlation of cross sectional areas with Motor distal latency, Sensory distal latency, Motor nerve conduction velocities, Sensory SNAP and Sensory nerve conduction velocity is observed with Pearson coefficient of 0.255,0.336,-0.082,-0.298 and -0.437 respectively.

DISCUSSION

The diagnosis of Carpal tunnel syndrome is based mainly on the patient's clinical history, signs and symptoms and use of electrodiagnostic tests. The value of provocative clinical tests in making diagnosis is often controversial and usually electrodiagnostic tests are used in confirmation of diagnosis as well as guide further management. The electrodiagnostic testing is quite expensive, invasive, not widely available and has shown a wide range of sensitivities.[9,10] Therefore, there has been a search for an alternative diagnostic modality in making the diagnosis of CTS.

Imaging techniques were not under consideration in the assessment of CTS until recently. Ultrasonographic detection of pathologic swelling of the median nerve by assessing its cross sectional area has been in recent times found to be the most convenient and least expensive method. Furthermore, anatomical evaluation and visualization of carpal tunnel is a strong point in the diagnosis and management of carpal tunnel syndrome, especially when there is a secondary cause of CTS.

Our study evaluated 146 wrists of 73 clinically suspected cases of carpal tunnel syndrome with high frequency ultrasonography and nerve conduction studies after the exclusion of 17 cases from the total 90 recruited cases. An equal numbers of age-matched controls were also evaluated with ultrasonography to establish normal values of sonographic parameters.

In our study, a female preponderance of disease was noted that is, 78.1% of the patients were females and 21.9 % were males with female to male ratio being 3.6:1. A similar study done by Singla et al[75] and Aggarwal et al[76] showed a female preponderance in cases of carpal tunnel syndrome. Another study done by Mondelli et al [77] on the incidence of carpal tunnel syndrome in a general population reported a female preponderance of the disease with 79.7% of cases being women and 20.3% men.

The mean age amongst the cases was found to be 45.34 ±11.18 years

with most of the patients aged between 41 to 50 years (37%). The youngest patient was of age 23 years and the oldest patient was of 79 years. Similar demographics in terms of mean age and age range in CTS cases were observed in a study done by Kamath et al[70], in which 46 wrists were studied in a total of thirty patients (6 male, 24 female with age range 22-78 yrs). Meanwhile, in the control group, the mean age was 44.07 ±12.34 and most of them aged between 41-50 years (30.1%). The youngest control was of age 23 years and the oldest was of 79 years.

The mean BMI amongst the cases was higher compared to the control group being 24.13 ± 3.58 kg/m², whilst in the control group, it was 22.32 ± 1.89 kg/m². The difference was statistically significant ($p<0.05$) and similar observation was reported by Junck et al[78] in his study done in 2015.Junck et al found a significant group difference in the BMI between the case and control groups, which is mean ± SD of 30.4 ± 6.38 in cases versus 25.0 ± 3.22 in controls (p value=0.025), which indicated an association between an increased BMI and carpal tunnel syndrome. Similarly, Wong et al[57] also found a statistically significant difference between the body mass index of the CTS patients (mean of 24.9 [SD 4.3]) and that of the controls (22.3 [SD 3.7]) ($P = 0.01$).

The occurrence of bifid nerve amongst the total recruited cases was 18.89%, whilst it was only 2% in the control group. Higher occurrence of bifid nerve in the patients of CTS was in concordance with the study done by Bayrak et al[79], who reported occurrence of bifid nerve among 19% cases of CTS.

The use of Provocative clinical tests in evaluation of CTS has reported varying degrees of sensitivity and specificity in the published literature. The sensitivity of Tinel test is reported between 38 to 100% and 42 to 92% for Phalen's test in the literature.[80] Similarly, the reported specificity for Tinel test ranges from 55 to 100% and 54 to 98% for the Phalen's test.[80] In our study, the sensitivity and specificity of Tinel test was 57.75% and 80.00% respectively compared to nerve conduction studies, while

Phalen's test showed slightly higher sensitivity and specificity of 60.56% and 81.33% respectively. The higher sensitivity of Phalen's test was in concordance with the studies done by Kuschner et al [81] and Rayegani et al.[41]

Various sonographic criteria for the diagnosis of CTS are swelling and hypoechogenicity of the median nerve, increase in cross-sectional area of median nerve at various levels of carpal tunnel, flattening of the median nerve and palmar bowing of the flexor retinaculum.[46,75] Among these parameters, the median nerve cross-sectional area is one of the most reliable in diagnosing CTS. Different levels of carpal tunnel have been used by various authors to calculate cross-sectional areas in their studies. In some studies measurement of cross-sectional area was performed at a single level, while others calculated cross sectional area at multiple levels. Duncan et al[53], Padua et al[82], Pinilla et al[83] and Moran *e*t al[84]used the carpal tunnel inlet to calculate increased cross sectional area of median nerve in CTS. Similarly, measurement of cross sectional area at both inlet and outlet of carpal tunnel was done by Paliwal et al [85] and Mohammadi et al[64], while multiple levels for cross sectional area measurement were used by Wong et al[57], Sarría *e*t al[54] and Nakamichi et al.[56] Measurement at both carpal tunnel inlet and outlet were done in the present study in keeping with findings of Paliwal et al that use of carpal tunnel outlet median nerve enlargement in addition to inlet increased sensitivity for diagnosing CTS.

In the present study, the median nerve mean CSA was 0.09 ± 0.03 cm^2 in CTS patients and 0.07± 0.01 cm^2 in controls at both inlet and outlet respectively.($p<0.001$)This statistically significant difference in the cross-sectional measurements of the median nerve between CTS patients and asymptomatic controls was also observed by Singla et al.[75] Buchberger et al[86] evaluated twenty-eight wrists of 25 patients with carpal tunnel syndrome and 28 wrists of 14 normal control subjects with high-frequency real-time ultrasonography and reported a mean CSA of 11.1 mm^2 in CTS

patients and 7.9 mm2 in the control group. Yesildag et al[87] reported a mean CSA was 14.9 mm^2 in CTS patients and 7.8 mm^2 in the control group and Duncan et al[53] reported a mean CSA was 13 mm^2 in CTS patients and 0.70 mm^2 in the control group. In another study, Mohammadi et al reported the mean cross-sectional area at the carpal tunnel inlet to be 11.4±1.7 mm^2[64] in the cases and 5.78±0.9 mm^2 in the controls (P<0.001), while at the tunnel outlet it was reported to be 9.9±1.2 mm^2 in the cases and 4.7±0.7 mm^2 in the controls(P<0.001). Similarly, Wong et al[57] found statistically significant differences in the median nerve cross-sectional area between CTS patients and controls at different levels of carpal tunnel(proximal to the carpal tunnel, at the tunnel inlet, and at the tunnel outlet).($P < 0.01$)

The reported cut-off values for diagnosing CTS at the level of carpal tunnel inlet vary from 8.5 and 15 mm^2 according to different studies with respective sensitivities ranging from 67% to 94% and specificities ranging from 57% to 97%.[64,82,88-90]Similarly, at the carpal tunnel outlet, these cutoff values have been reported from 8.5 to 13 mm^2 with respective sensitivity ranging from 57% to 75% and specificity ranging from 51% to 92%.[64,82,91,92] In our study, the best discriminatory criterion for ultrasonographic diagnosis of CTS was the median nerve cross sectional area of >0.09 cm^2 (9 mm^2) at both carpal tunnel inlet and outlet. Similar cut off values for cross-sectional areas have been reported in the studies done by Duncan et al[53], Mohammadi et al[64], Singla et al[75], Aggarwal et al[76] and Zhang et al.[68]Duncan et al[53] reportedly found that the quantitative assessment of the median nerve with a cross-sectional area larger than 0.09 cm^2 was highly predictive of carpal tunnel syndrome. Mohammadi et al[64]observed that the best cutoff value of the cross-sectional area at the tunnel inlet and outlet was 8.5 mm^2.The cut-off in Indian studies by Singla et al[75] and Aggarwal et al[76]was found to be 8.8 mm^2 and 9.0 mm^2 respectively. Similarily, Zhang et al[68]et observed that the cut-off value of 9.05 mm^2 to be reliable parameter in diagnosing CTS

in his study of 77 patients. In our study, the respective sensitivity and specificity at the inlet for this cut off value (9.0 mm²) was calculated to be 66% and 79% (Area under ROC-0.777), while at outlet these value measured 68% and 80% (Area under ROC-0.758). Similar values for sensitivity and specificity for cross-sectional areas have been reported by Sarría et al[54], Ashraf et al[93], Sarraf et al[94] Dalili et al[95]and Altinok et al.[96]

The overall sensitivity and specificity of ultrasonography to detect carpal tunnel syndrome by the increase in the cross sectional area of the median nerve (when increased above cut-off at either inlet/outlet or both) was calculated to be 70.42% and 80.00% as compared to nerve conduction studies. This increase in the sensitivity of ultrasonography to diagnose CTS, when measuring cross sectional areas at both carpal tunnel inlet and outlet was in keeping with findings of Paliwal et al.[85]

The other three parameters evaluated along with cross sectional areas include- Nerve flattening, Nerve hypoechogenicity and Palmar bowing of flexor retinaculum. The usefulness of these parameters in diagnosing CTS has been demonstrated by various studies including Buchberger et al[14], Sarría et al[54], Wong et al[57] and Mallouhi et al.[62]

The Nerve flattening and hypoechogenicity demonstrated lower sensitivities in detecting CTS as compared to Cross-sectional area, however, had higher specificities. Higher sensitivities of cross sectional as compared to these parameters was in concordance with studies done by Wong et al[57], Yesildag et al[87], Ghaffar et al[67] and Omar et al.[97] The reported sensitivity of nerve flattening as a diagnostic parameter in the literature ranges from 37% to 100%.[53,62,86,87,98]Yesildag et al[87] reported sensitivity of flattening ratio in diagnosing CTS to be as low as 37%. The studies done by Mallouhi et al[62] and Keberle et al[98] reported sensitivity of flattening ratio to be 60% and 100% respectively. In our study, the nerve flattening was observed in 27.40% of total hands (in cases) evaluated corresponding to sensitivity of 50.70%, which is close to the study done by

Mallouhi et al[62] Similarly, the Nerve Hypoechogenicity was found in 29.45% of total hands (in cases) evaluated corresponding with sensitivity and specificity of 56.34% and 96.00% respectively.

The palmar bowing of flexor retinaculum was the least sensitive criteria among all the parameters with a sensitivity of 25.35% and specificity of 89.33% in our study using cut-off of 4 mm at level of outlet. These findings are in agreement with the study done by Altinok et al [96], who reported sensitivity of 20% and specificity of 97.50% for flattening ratio at a similar cut-off for palmar bowing of flexor retinaculum.

The Statistical analysis showed a significant correlation between the cross-sectional area of the median nerve measured by ultrasound with electrodiagnostic measurements. There was a statistically significant positive correlation of cross-sectional areas at both inlet and outlet with Motor and sensory distal latency, while a negative correlation was established with motor nerve conduction velocities, sensory SNAP and sensory nerve conduction velocities. The correlation of cross-sectional areas with motor CMAP and motor nerve conduction velocity, however, was found to statistically insignificant. A significant correlation of cross sectional areas with electrodiagnostic parameters was also observed in their studies done by Singla et al[75],Kwon et al[99]and El Habashy et al.[100]

Thus, according to our study ultrasonography can be considered as a useful tool for diagnosis of CTS as per sensitivity/ specificity patterns of our study as well as other studies. The ultrasonographic quantitative measurement of the CSA of the median nerve is a particularly useful discriminatory diagnostic tool and along with other ancillary parameters like nerve flattening nerve, nerve hypoechogenicity and palmar bowing can very well be used as a screening tool in CTS.

The strength of our study was a clear definition of anatomical landmarks on ultrasonography for inlet and outlet of carpal tunnel to evaluate the median nerve and to avoid the variability of the results. Secondly, we also included patients with all grades of severity to avoid the bias of the results,

as a few previously conducted studies didn’t take patients with mild diagnostic abnormalities. The limitation of our study was that it was a single-center study and included small sample size of patients.

SUMMARY AND CONCLUSION

Summary

1. The present study was conducted at the Department of Radiodiagnosis and Neurology, Dayanand Medical College and Hospital, Ludhiana.

2. 73 out of total 90 recruited patients with clinically suspected carpal tunnel syndrome, who were referred to the Department of Radiodiagnosis, over a period of 1 year from December 2018 to December 2019, were included in the study. The study also included an equal number of age-matched asymptomatic controls.

3. The age range of patients was 23-79 years (57 females, 16 males) and of controls was 23-79 years (50 females, 23 males).

4. The BMI among the cases ranged from 16.8 to 40.3 kg/m² with a mean value of 24.13±3.58 kg/m², while among the controls it ranged from 18 to 28 kg/m² with a mean value of 22.32±1.89 kg/m².

5. The most common presenting complaint was numbness of hands. Among cases, 68.5% of patients had bilateral symptoms and 31.5% had unilateral symptoms.

6. Amongst provocative clinical tests, the sensitivity of Phalen's test (Sensitivity 60.56%) was slightly higher as compared to Tinel test (Sensitivity 57.75%).

7. High resolution ultrasonography was performed on cases as well as controls on either LOGIQ E9 or Phillips IU22 machine using a 6-15 Mhz linear probe. Parameters evaluated on ultrasonography included echogenicity of the nerve, cross-sectional area of nerve at inlet and outlet of carpal tunnel, flattening of median nerve and bowing of palmar retinaculum. The cases were also subjected to Nerve conduction studies.

8. The mean cross-sectional area at both inlet and outlet was 0.09 ± 0.03 cm² in the cases, while in control group the mean CSA at both inlet and outlet was 0.07± 0.01 cm².(p value <0.001).

9. The best discriminatory criterion for ultrasonographic diagnosis of CTS

was median nerve cross-sectional area of >0.09 cm^2 (9 mm^2) at both carpal tunnel inlet and outlet. Reciever Operator Curves revealed that a cut off of 0.09 cm^2 at both inlet and outlet yielded maximum sensitivity and specificity. The calculated sensitivity and specificity were 66 % and 79 % respectively at inlet and 68 % and 80 % respectively at outlet.

10. The overall sensitivity and specificity of ultrasonography to detect carpal tunnel syndrome by the increase in the cross sectional area of the median nerve (when increased above cut-off at either inlet/outlet or both) was calculated to be 70.42% and 80.00% as compared to nerve conduction studies.

11. Cross-sectional areas showed higher sensitivity in diagnosing CTS as compared to other parameters like nerve hypoechogenicity, nerve flattening and palmar bowing.

12. The statistical analysis of the data showed a significant correlation between the cross-sectional areas of the median nerve at inlet and outlet measured by ultrasonography and results of electrodiagnostic parameters.

Conclusion

In our study, the results can be summarized as-

- Carpal tunnel syndrome is common in the middle age group with higher risk in females.
- The best discriminatory criterion for ultrasonographic diagnosis of CTS is median nerve cross sectional area of >0.09 cm^2 (9 mm^2) at both carpal tunnel inlet and outlet. The respective sensitivity and specificity for this cut-off is as follows–

  -At the level of carpal tunnel inlet, the sensitivity is 66% and specificity is 79%.

  -At the level of the carpal tunnel outlet, the sensitivity is 68%and specificity is 80%.
- The overall sensitivity and specificity of ultrasonography to detect carpal tunnel syndrome by the increase in the cross sectional area of the median nerve (when increased above cut-off at either inlet/outlet or

both) was calculated to be 70.42% and 80.00% as compared to nerve conduction studies.

- The use of cross sectional areas along with other ultrasonographic parameters like nerve hypoechogenicity, nerve flattening and palmar bowing makes it a useful diagnostic tool in objective assessment of patients suspected of carpal tunnel syndrome complementing nerve conduction studies.
- Ultrasonography has been found to be more widely available as compared to nerve conduction studies. It is also less time consuming (average time 15 minutes), non-invasive and cost-effective as compared to the nerve conduction studies. Along with this, Ultrasonography has also the advantage of giving information about the morphology of the nerve and its surrounding structures.
- Given its advantages, High Frequency Ultrasonography can be thus be used as a first line investigation complementing the electrodiagnostic methods to quickly screen the patients clinically suspected patient of CTS, which is especially true for resource conscious countries with large populations.

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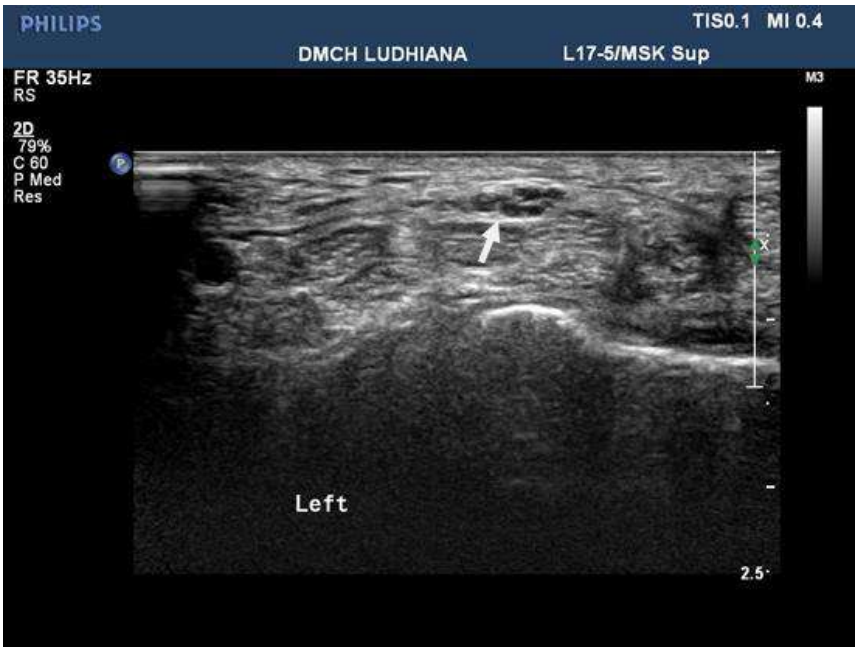
Case 1: Normal sonographic appearance of median nerve

a)

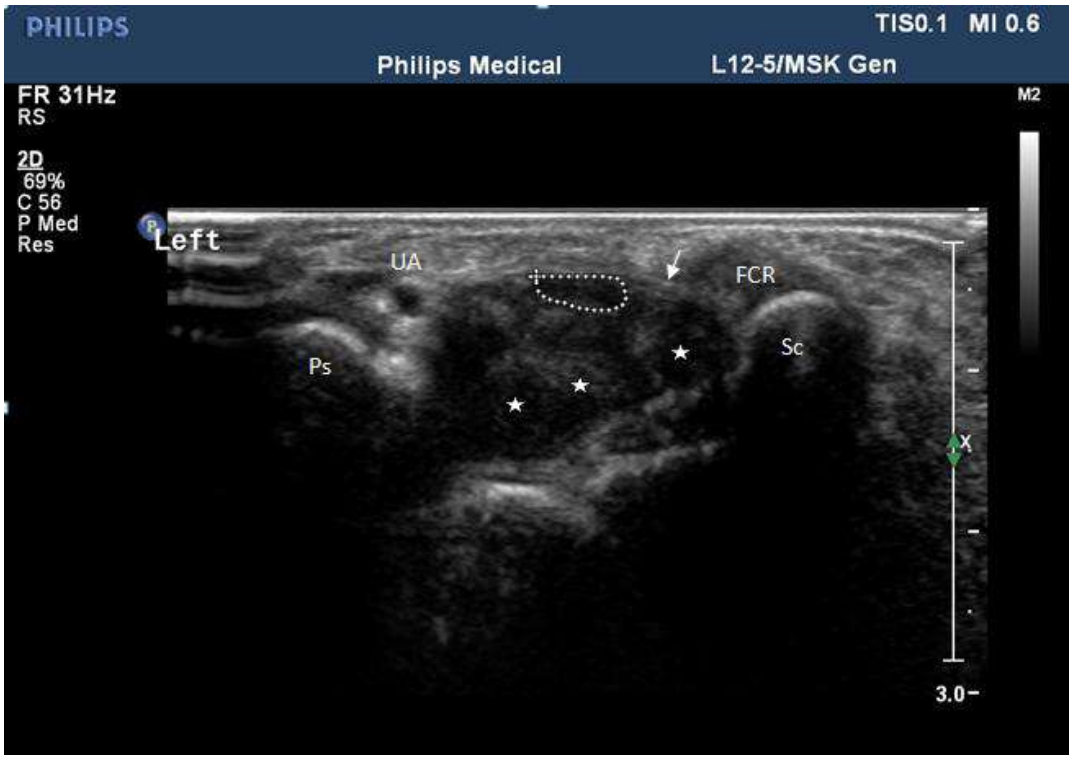


b)

a) Longitudinal sonogram of wrist shows normal appearance of median nerve (white arrows) in carpal tunnel with flexor tendons (white star).

b) Typical Axial sonogram of wrist showing 'Honeycomb appearance' of median nerve (white arrow)

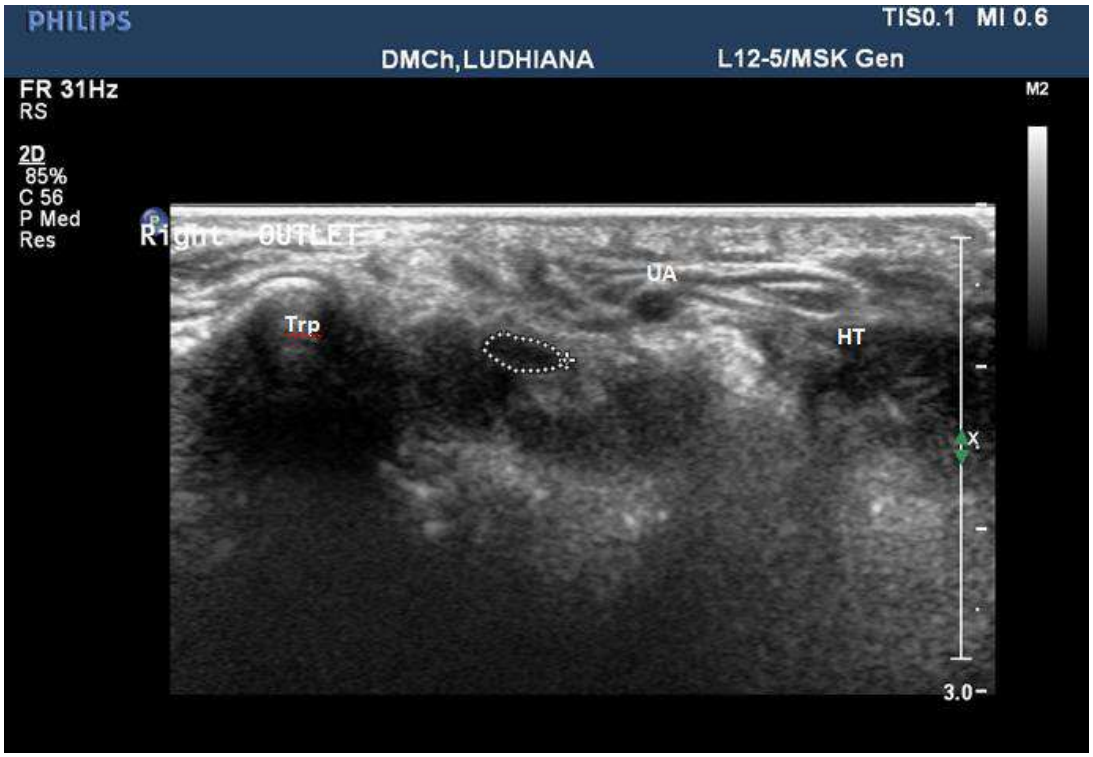
Case 2: Sonographic appearance of normal carpal tunnel inlet.



Typical appearance of carpal tunnel inlet on transverse sonogram

Stars-Flexor tendons, Dotted circle-Median nerve, Arrow-Flexor retinaculum, Ps-Pisiform, Sc-Scaphoid, FCR-Flexor carpi ulnaris and UA-Ulnar artery.

Case 3: Sonographic appearance of normal carpal tunnel outlet



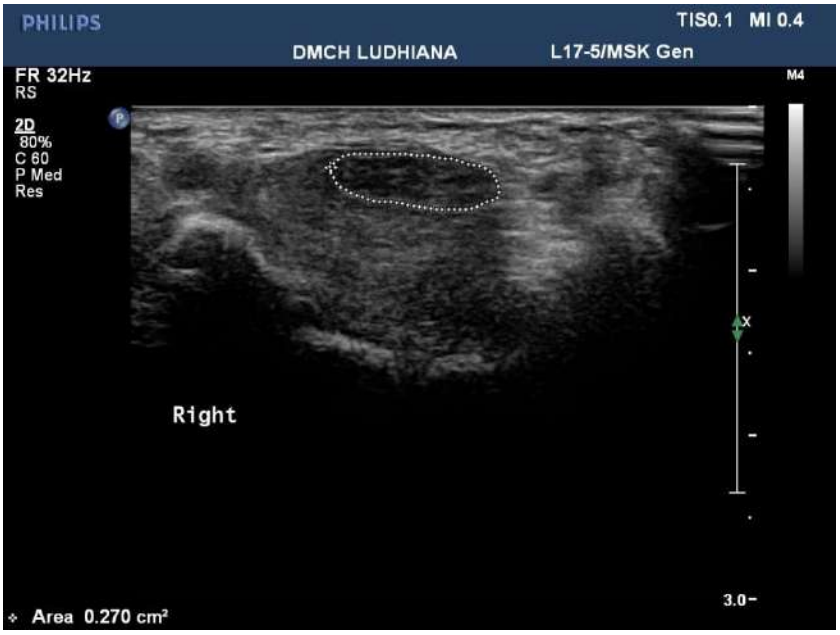
Typical appearance of carpal tunnel outlet on transverse sonogram

Trp-Trapezoid, Dotted circle-Median nerve, UA-Ulnar artery and HT-Hypothenar muscles.

Case 4: Sonographic appearance of median nerve in cases of CTS at different levels of carpal tunnel.

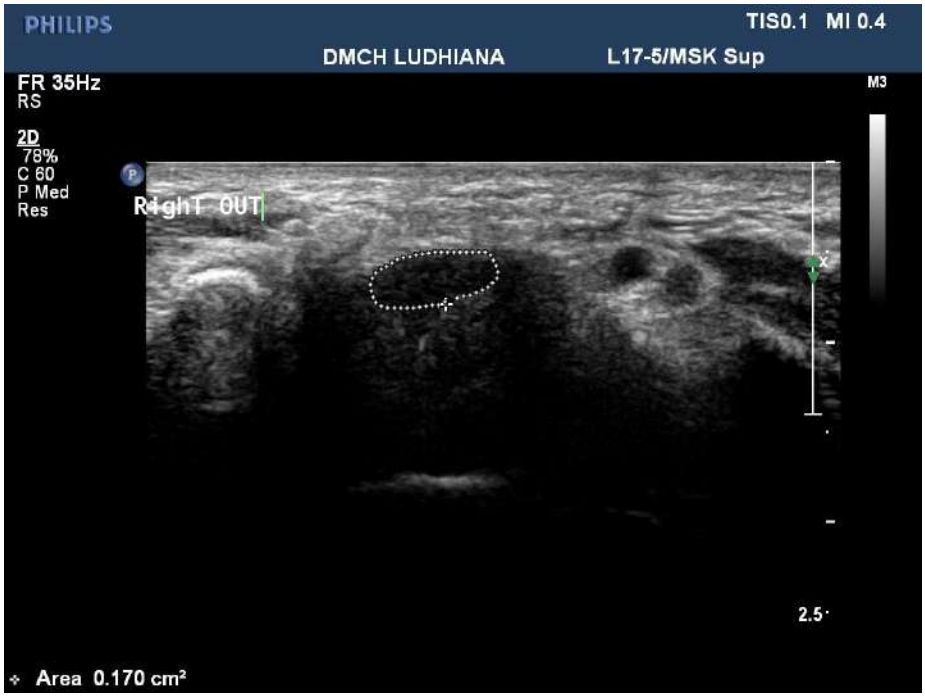
a) Axial sonogram of wrist in a 56 year old female patient with known diagnosis of carpal tunnel syndrome shows presence of enlarged (CSA-0.134 cm^2) and hypoechoic median nerve (dotted ellipse) with loss of fascicular details at the level of carpal tunnel inlet.

b) Axial sonogram of wrist in a 42 year old female patient with carpal tunnel syndrome shows markedly enlarged and hypoechoic median nerve (dotted ellipse) nearly at the level of carpal tunnel outlet.

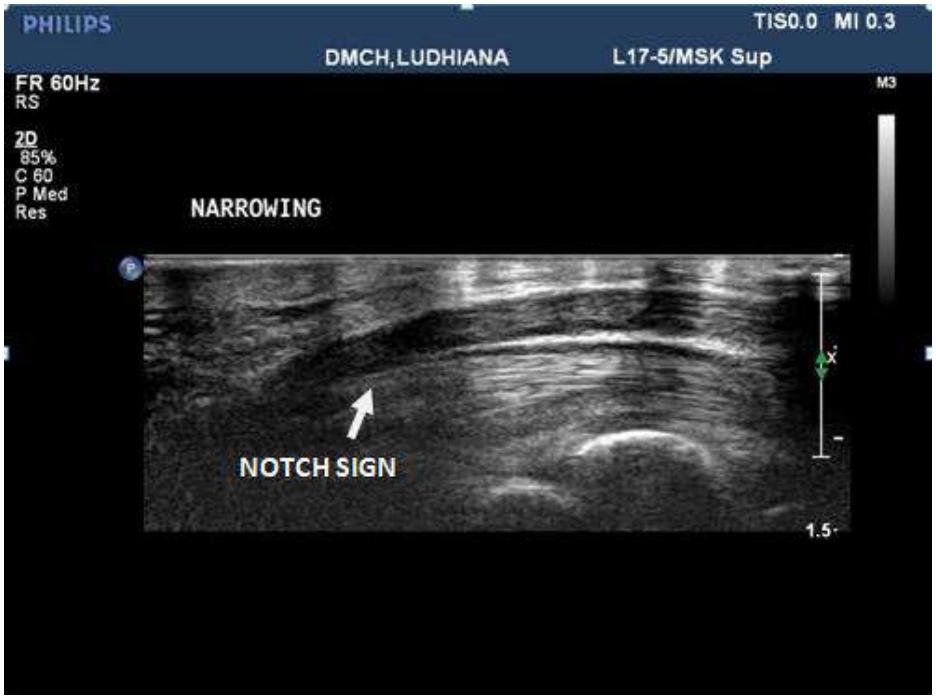


c) Transverse sonogram depicting markedly enlarged and hypoechoic median nerve (dotted ellipse) in a patient with known CTS at level of inlet of carpal tunnel.

d) In a patient with severe CTS, edematous and hypoechoic median nerve can be appreciated with increased cross sectional area (measuring approximately 0.160 cm^2) on transverse section.

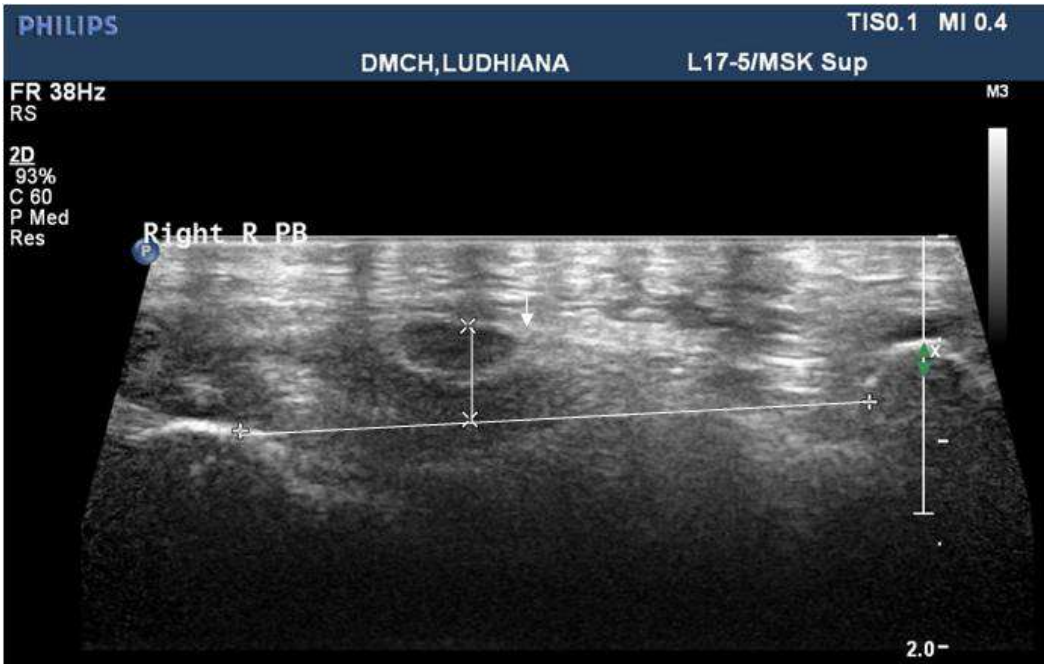


e) Transvere sonogram in CTS patient shows enlarged median nerve with loss of echogenic margins and fascicular details.



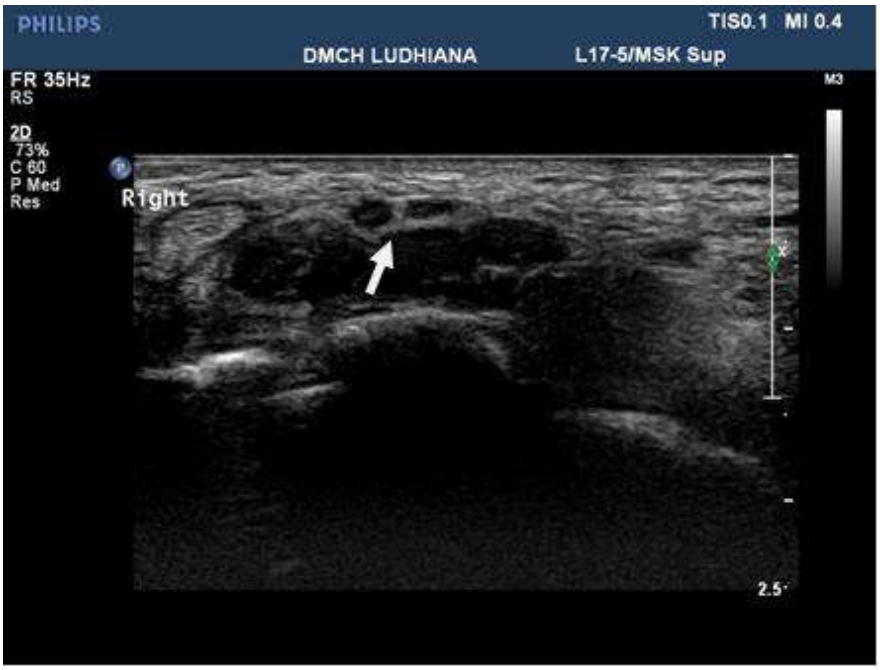
f) Longitudinal section of carpal tunnel depiciting compression of median nerve giving ‘Notch sign’.

Case 5: Palmar bowing of flexor retinaculum



Transverse section depicting palmar bowing of flexor retinaculum in a known case of Carpal tunnel syndrome

Case 6: Bifid median nerve



(a)

(b)

Axial sonogram of wrist in a 58 year male patient with clinical symptoms of carpal tunnel syndrome shows presence of bifid median nerve (white arrow) a) at the level proximal to carpal tunnel b) at the level of carpal tunnel inlet.

Case 7: Persistent median artery with bifid median nerve

(a)

(b)

Transverse sonograms show in a 37 year old female with clinical suspicion of carpal tunnel syndrome shows (a) presence of persistent median artery (white arrow) between ulnar and radial bundles of bifid median nerve (b) Doppler images show presence of color flow within the persistent median artery with no intraluminal thrombosis.

KEY TO MASTER CHART

+	Positive
-	Negative
B/l	Bilateral
BMI	Body mass Index
C/C	Chief complaints
CMAP	Compound muscle action potential
CSA	Cross sectional area
CTS	Carpal Tunnel Syndrome
DL	Distal latency
F	Female
I/O	Inlet/Outlet
L	Left
Lt	Left
M	Male
R	Right
Rt	Right
S No.	Serial number
USG	Ultrasound
YRS	Years

S.No.	NAME	AGE (Yrs)	SEX	BMI (kg/m²)	MRD	C/C	Laterality of Symptoms	TINEL TEST	PHALEN'sTEST	Ultrasonc				
										Nerve Hypoechogenicity/ Swelling	CSA(cm2)			
										Hypoechoic	Rt Inlet	Rt Outlet	I/O ratio	Lt Inlet
1	GK	47	F	16.8	622233	Pain	Right	Positive right	Positive right	Right outlet	0.092	0.099	0.93	0.069
2	KK	46	F	40.3	629949	Pain and numbness	B/l	Positive b/l	Positive b/l	B/l outlet	0.092	0.094	0.98	0.091
3	HK	40	F	33.6	623011	Numbness	Right	Positive b/l	Positive b/l	No	0.05	0.05	1	0.07
4	SK	47	F	29.4	622262	Numbness	B/l	Positive b/l	Positive b/l	Left outlet	0.067	0.087	0.77	0.081
5	PK	38	F	28.8	456289	Pain and numbness	Right	Positive right	Positive right	No	0.074	0.092	0.8	0.081
6	NK	32	F	27	642634	Numbness	Left	Positive left	Positive left	Left outlet	0.092	0.098	0.94	0.081
7	SB	44	F	26.4	4130	Pain	B/l	Positive right	Positive b/l	B/l outlet	0.092	0.139	0.66	0.128
8	SB	40	F	25.4	414015	Pain	Left	Negative b/l	Positive left	Left outlet	0.067	0.082	0.81	0.092
9	RB	40	F	25.4	680520	Numbness	B/l	Positive b/l	Positive b/l	No	0.086	0.08	1.07	0.076
10	JC	31	F	24.8	655063	Numbness	B/l	Negative b/l	Positive right	B/l inlet and outlet	0.092	0.1	0.92	0.111
11	P	58	M	30.9	639903	Pain	Right	Positive b/l	Positive b/l	No	0.09	0.11	0.81	0.07
12	MK	56	F	24.3	706283	Numbness	B/l	Positive b/l	Positive b/l	B/l inlet and outlet	0.169	0.104	1.6	0.247
13	KS	46	M	25.7	713491	Numbness	B/l	Negative b/l	Negative b/l	No	0.077	0.065	1.2	0.072
14	GK	50	F	24.6	706258	Numbness	B/l	Positive right	Positive right	No	0.1	0.1	1	0.07
15	PG	47	F	25.1	715003	Numbness	Left	Positive b/l	Positive b/l	B/l inlet and outlet	0.129	0.158	0.81	0.115
16	KP	45	M	25.4	709280	Numbness	B/l	Negative b/l	Negative b/l	No	0.08	0.075	1.1	0.081
17	JK	40	F	20.3	728985	Numbness	B/l	Positive b/l	Positive b/l	B/l inlet and outlet	0.109	0.144	0.76	0.123
18	DK	48	F	24.2	116432	Numbness	B/l	Positive b/l	Positive b/l	No	0.079	0.088	0.9	0.084
19	DS	48	M	23.9	776890	Numbness	Left	Positive left	Positive left	Left inlet and outlet	0.095	0.09	1.01	0.113
20	JS	68	M	20.2	781650	Numbness	Right	Negative b/l	Negative b/l	Right outlet	0.092	0.099	0.93	0.083
21	N	42	F	25	670108	Numbness	B/l	Positive b/l	Positive b/l	B/l inlet and outlet	0.162	0.27	0.6	0.101
22	R	38	F	20.8	788520	Pain and numbness	B/l	Negative b/l	Negative b/l	No	0.061	0.056	1.09	0.056
23	JK	57	F	23.1	795787	Numbness	Right	Negative b/l	Positive right	No	0.069	0.071	0.97	0.08
24	GK	57	F	27.2	805725	Numbness	Right	Negative b/l	Negative b/l	B/l inlet and outlet	0.092	0.114	0.081	0.095
25	VS	55	M	23.4	709227	Numbness	B/l	Negative b/l	Negative b/l	No	0.101	0.092	1.1	0.098
26	V	38	F	26.6	800747	Numbness	B/l	Positive b/l	Positive b/l	B/l inlet and outlet	0.147	0.159	0.92	0.149
27	SS	44	M	23.5	657091	Numbness	B/l	Negative b/l	Negative b/l	Right inlet	0.099	0.098	1.01	0.099
28	LK	55	F	25.6	27393	Numbness	B/l	Negative b/l	Negative b/l	B/l inlet and outlet	0.146	0.16	0.91	0.107
29	BJ	60	M	26.1	337136	Numbness	B/l	Negative b/l	Negative b/l	Right inlet	0.112	0.117	0.96	0.09
30	JS	38	M	22.5	33461	Numbness	B/l	Negative b/l	Negative b/l	No	0.078	0.076	1.02	0.086
31	MA	45	M	23.5	837556	Numbness	B/l	Positive b/l	Positive b/l	B/l inlet	0.133	0.094	1.41	0.111
32	RKT	35	F	22	639736	Numbness	B/l	Positive b/l	Positive b/l	Right outlet	0.092	0.104	0.88	0.093
33	SK	32	F	22	846012	Numbness	B/l	Positive b/l	Positive b/l	No	0.09	0.1	0.9	0.072
34	GK	42	F	25.6	768864	Numbness	B/l	Negative b/l	Negative b/l	Right outlet	0.12	0.113	1.06	0.104
35	R	36	F	21.9	872381	Pain and numbness	B/l	Positive b/l	Positive b/l	Right inlet	0.101	0.093	1.09	0.094
36	RK	48	F	23.3	871578	Pain	Left	Positive left	Positive left	B/l inlet and outlet	0.116	0.114	1.02	0.101
37	HK	47	F	33.1	872919	Numbness	B/l	Positive b/l	Positive b/l	Left outlet	0.096	0.093	1.03	0.1
38	BK	50	F	24.4	896122	Pain and numbness	B/l	Negative b/l	Negative b/l	Right inlet	0.07	0.06	1.17	0.07
39	NS	79	M	24.5	902455	Numbness	B/l	Negative b/l	Negative b/l	No	0.081	0.061	1.33	0.065
40	M	32	F	19.2	904808	Pain and numbness	B/l	Negative b/l	Negative b/l	No	0.073	0.084	0.87	0.072
41	ND	53	F	23.3	933530	Numbness	B/l	Positive b/l	Positive b/l	B/l inlet and outlet	0.109	0.105	1.04	0.092
42	KS	46	M	23.7	713491	Numbness	B/l	Positive b/l	Negative b/l	B/l inlet	0.108	0.1	1.08	0.11
43	VS	74	F	20.4	861802	Pain	B/l	Negative b/l	Negative b/l	No	0.079	0.077	1.02	0.067
44	GR	39	F	20.2	863309	Numbness	B/l	Negative b/l	Negative b/l	No	0.054	0.062	0.87	0.088
45	KS	50	F	22.3	474107	Numbness	Right	Negative b/l	Negative b/l	No	0.068	0.07	0.97	0.064
46	BA	41	F	31.6	4147	Pain	Left	Negative b/l	Negative b/l	No	0.057	0.065	0.87	0.057
47	RK	37	F	19.6	671298	Pain and numbness	Left	Positive left	Negative b/l	No	0.071	0.079	0.9	0.094
48	HK	28	F	25.4	681763	Numbness	B/l	Negative b/l	Negative b/l	No	0.07	0.08	0.87	0.06
49	RR	26	F	22.7	627901	Pain and numbness	B/l	Positive b/l	Positive b/l	No	0.048	0.043	1.11	0.044
50	JK	50	F	26.4	674544	Numbness	B/l	Negative b/l	Negative b/l	NO	0.055	0.056	0.98	0.049
51	KR	47	F	23.5	728900	Numbness	B/l	Negative b/l	Negative b/l	No	0.057	0.066	0.86	0.068
52	GD	49	F	24.2	704857	Pain	B/l	Negative b/l	Negative b/l	No	0.055	0.078	0.7	0.056
53	VK	62	F	24.3	705888	Pain	Left	Positive b/l	Positive b/l	No	0.126	0.107	1.17	0.11
54	KK	29	F	21.3	736621	Numbness	Left	Negative b/l	Negative b/l	No	0.066	0.069	0.96	0.059
55	P	23	M	21.4	744596	Pain and	Right	Negative b/l	Negative b/l	No	0.061	0.062	0.98	0.06
56	SR	55	F	22.7	786749	Numbness	B/l	Negative b/l	Negative b/l	No	0.08	0.084	0.95	0.079
57	KK	51	F	23.1	40587	Numbness	B/l	Negative b/l	Negative b/l	No	0.093	0.093	1	0.081
58	NS	45	M	22.9	782067	Numbness	Left	Negative b/l	Negative b/l	No	0.083	0.078	1.06	0.072
59	BK	36	F	21	814149	Numbness	B/l	Negative b/l	Negative b/l	No	0.053	0.057	0.93	0.071
60	BK	51	F	22.7	306390	Numbness	B/l	Negative b/l	Negative b/l	No	0.079	0.067	1.18	0.074
61	KS	52	M	23.5	5025	Pain	Left	Negative b/l	Negative b/l	No	0.054	0.062	0.87	0.068
62	JK	58	F	22.3	51413	Pain and numbness	B/l	Negative b/l	Negative b/l	No	0.067	0.07	0.96	0.063
63	GK	45	F	21.5	827954	Pain	B/l	Negative b/l	Negative b/l	No	0.068	0.058	1.17	0.079
64	P	26	F	19.3	847173	Numbness	B/l	Negative b/l	Negative b/l	No	0.07	0.073	0.96	0.063
65	K	54	F	21.6	862428	Pain	B/l	Negative b/l	Positive b/l	No	0.098	0.105	0.93	0.101
66	M	34	F	21.6	780873	Numbness	B/l	Positive b/l	Positive b/l	No	0.145	0.109	1.33	0.097
67	RS	43	F	24.2	842414	Numbness	B/l	Negative b/l	Negative b/l	No	0.085	0.079	1.07	0.08
68	R	32	F	22.8	7919	Pain	B/l	Negative b/l	Negative b/l	No	0.032	0.028	1.14	0.033
69	MK	52	F	23.4	870990	Numbness	Left	Negative b/l	Negative b/l	No	0.077	0.078	0.99	0.067
70	MB	45	F	22.4	607285	Numbness	B/l	Positive b/l	Positive b/l	B/l inlet and outlet	0.11	0.128	0.86	0.143
71	SC	71	M	24.5	295726	Numbness	Right	Positive b/l	Negative b/l	No	0.08	0.108	0.74	0.084
72	V	30	F	22	753775	Pain and numbness	B/l	Negative b/l	Negative b/l	No	0.076	0.084	0.9	0.077
73	S	35	F	23.6	903362	Pain and numbness	Left	Positive b/l	Positive b/l	No	0.104	0.103	1.01	0.099
						CONTROLS								

S.No.	NAME	AGE (Yrs)	SEX	BMI (kg/m²)	MRD	C/C	Laterality of Symptoms	TINEL TEST	PHALEN'sTEST	Ultrasonc				
										Nerve Hypoechogenicity/ Swelling	CSA(cm2)			
										Hypoechoic	Rt Inlet	Rt Outlet	I/O ratio	Lt Inlet
1	AK	58	F	25.1	-	Asymptomatic	-	Negative	Negative	No	0.05	0.078	0.64	0.071
2	A	30	F	21.2	-	Asymptomatic	-	Negative	Negative	No	0.066	0.07	0.94	0.08
3	A	40	F	23.6	-	Asymptomatic	-	Negative	Negative	No	0.063	0.074	0.85	0.06
4	B	34	M	22.5	-	Asymptomatic	-	Negative	Negative	No	0.053	0.074	0.72	0.054
5	S	36	F	24	-	Asymptomatic	-	Negative	Negative	No	0.072	0.085	0.85	0.077
6	D	32	M	23.6	-	Asymptomatic	-	Negative	Negative	No	0.055	0.057	0.96	0.073
7	S	42	F	22.4	-	Asymptomatic	-	Negative	Negative	No	0.053	0.067	0.79	0.076
8	D	25	M	18	-	Asymptomatic	-	Negative	Negative	No	0.063	0.045	1.4	0.046
9	E	25	M	19.5	-	Asymptomatic	-	Negative	Negative	No	0.053	0.045	1.18	0.061
10	G	32	M	23.4	-	Asymptomatic	-	Negative	Negative	No	0.063	0.064	0.98	0.068
11	H	44	M	21.6	-	Asymptomatic	-	Negative	Negative	No	0.056	0.065	0.86	0.063
12	H	40	M	21.6	-	Asymptomatic	-	Negative	Negative	No	0.068	0.071	0.96	0.059
13	H	40	F	23.6	-	Asymptomatic	-	Negative	Negative	No	0.064	0.065	0.98	0.059
14	H	31	M	22.5	-	Asymptomatic	-	Negative	Negative	No	0.062	0.06	1.03	0.06
15	J	58	F	22.2	-	Asymptomatic	-	Negative	Negative	No	0.052	0.066	0.79	0.058
16	MK	56	F	21	-	Asymptomatic	-	Negative	Negative	No	0.06	0.058	1.03	0.078
17	N	46	F	23.6	-	Asymptomatic	-	Negative	Negative	No	0.072	0.07	1.03	0.065
18	P	50	F	20	-	Asymptomatic	-	Negative	Negative	No	0.071	0.064	1.11	0.05
19	S	47	F	23	-	Asymptomatic	-	Negative	Negative	No	0.076	0.079	0.96	0.069
20	S	45	M	25.6	-	Asymptomatic	-	Negative	Negative	No	0.061	0.066	0.92	0.057
21	S	40	F	22.2	-	Asymptomatic	-	Negative	Negative	No	0.051	0.064	0.8	0.049
22	R	48	M	22.1		Asymptomatic	-	Negative	Negative	No	0.062	0.063	0.98	0.068
23	S	48	M	23.6	-	Asymptomatic	-	Negative	Negative	No	0.073	0.074	0.99	0.07
24	B	68	M	20.2	-	Asymptomatic	-	Negative	Negative	No	0.063	0.064	0.98	0.072
25	B	42	F	18.6	-	Asymptomatic	-	Negative	Negative	No	0.084	0.082	1.02	0.078
26	A	38	F	22	-	Asymptomatic	-	Negative	Negative	No	0.087	0.086	1.01	0.082
27	N	38	F	22.6	-	Asymptomatic	-	Negative	Negative	No	0.088	0.084	1.05	0.087
28	K	40	F	22.4	-	Asymptomatic	-	Negative	Negative	No	0.079	0.086	0.92	0.069
29	P	45	F	23.6	-	Asymptomatic	-	Negative	Negative	No	0.088	0.088	1	0.07
30	D	36	F	24	-	Asymptomatic	-	Negative	Negative	No	0.076	0.086	0.88	0.082
31	A	26	M	22	-	Asymptomatic	-	Negative	Negative	B/l inlet and outlet	0.1	0.1	1	0.102
32	A	28	F	22.4	-	Asymptomatic	-	Negative	Negative	No	0.088	0.089	0.99	0.078
33	P	56	F	22.4	-	Asymptomatic	-	Negative	Negative	No	0.061	0.066	0.92	0.057
34	J	70	M	22.4	-	Asymptomatic	-	Negative	Negative	No	0.051	0.064	0.8	0.049
35	P	47	F	18	-	Asymptomatic	-	Negative	Negative	No	0.062	0.063	0.98	0.068
36	R	50	F	19.6	-	Asymptomatic	-	Negative	Negative	No	0.073	0.074	0.99	0.07
37	GK	79	F	25.1	-	Asymptomatic	-	Negative	Negative	No	0.063	0.064	0.98	0.072
38	S	32	F	21.2	-	Asymptomatic	-	Negative	Negative	No	0.084	0.082	1.02	0.078
39	S	53	F	23.6	-	Asymptomatic	-	Negative	Negative	No	0.087	0.086	1.01	0.082
40	M	46	F	22.5	-	Asymptomatic	-	Negative	Negative	No	0.062	0.063	0.98	0.068
41	G	74	F	24	-	Asymptomatic	-	Negative	Negative	No	0.073	0.074	0.99	0.07
42	SD	54	F	23.6	-	Asymptomatic	-	Negative	Negative	No	0.063	0.064	0.98	0.072
43	D	52	M	22.4	-	Asymptomatic	-	Negative	Negative	No	0.084	0.082	1.02	0.078
44	P	39	F	18	-	Asymptomatic	-	Negative	Negative	No	0.076	0.082	0.93	0.076
45	JC	50	F	19.5	-	Asymptomatic	-	Negative	Negative	No	0.063	0.068	0.93	0.071
46	K	41	F	23.4	-	Asymptomatic	-	Negative	Negative	No	0.051	0.064	0.8	0.049
47	M	37	F	21.6	-	Asymptomatic	-	Negative	Negative	No	0.062	0.063	0.98	0.068
48	D	28	F	21.6	-	Asymptomatic	-	Negative	Negative	No	0.073	0.074	0.99	0.07
49	Y	26	F	23.6	-	Asymptomatic	-	Negative	Negative	No	0.063	0.064	0.98	0.072
50	D	50	M	22.5	-	Asymptomatic	-	Negative	Negative	No	0.064	0.064	1	0.065
51	K	47	F	22.2	-	Asymptomatic	-	Negative	Negative	No	0.063	0.063	1	0.064
52	U	49	M	21	-	Asymptomatic	-	Negative	Negative	B/l inlet and outlet	0.091	0.091	1	0.09
53	SK	62	F	23.6	-	Asymptomatic	-	Negative	Negative	No	0.053	0.045	1.18	0.061
54	A	29	F	20	-	Asymptomatic	-	Negative	Negative	No	0.063	0.064	0.98	0.068
55	SJ	23	M	23	-	Asymptomatic	-	Negative	Negative	No	0.056	0.065	0.86	0.063
56	A	55	M	25.6	-	Asymptomatic	-	Negative	Negative	No	0.068	0.071	0.96	0.059
57	G	51	M	22.2	-	Asymptomatic	-	Negative	Negative	No	0.064	0.065	0.98	0.059
58	S	45	M	22.1	-	Asymptomatic	-	Negative	Negative	No	0.062	0.06	1.03	0.06
59	RK	36	F	19.3	-	Asymptomatic	-	Negative	Negative	No	0.052	0.066	0.79	0.058
60	R	51	F	20	-	Asymptomatic	-	Negative	Negative	No	0.06	0.058	1.03	0.078
61	P	52	M	26	-	Asymptomatic	-	Negative	Negative	No	0.072	0.07	1.03	0.065
62	J	58	F	22.3	-	Asymptomatic	-	Negative	Negative	No	0.071	0.064	1.11	0.05
63	N	45	F	24.6	-	Asymptomatic	-	Negative	Negative	No	0.076	0.079	0.96	0.069
64	N	26	F	28	-	Asymptomatic	-	Negative	Negative	No	0.056	0.065	0.86	0.063
65	M	54	F	22	-	Asymptomatic	-	Negative	Negative	No	0.068	0.071	0.96	0.059
66	R	34	F	23.8	-	Asymptomatic	-	Negative	Negative	No	0.064	0.065	0.98	0.059
67	S	43	F	22.3	-	Asymptomatic	-	Negative	Negative	No	0.053	0.045	1.18	0.061
68	M	32	F	22.6	-	Asymptomatic	-	Negative	Negative	No	0.063	0.064	0.98	0.068
69	A	52	F	21	-	Asymptomatic	-	Negative	Negative	No	0.056	0.065	0.86	0.063
70	D	45	F	22	-	Asymptomatic	-	Negative	Negative	No	0.068	0.071	0.96	0.059
71	JS	71	M	24.1	-	Asymptomatic	-	Negative	Negative	B/l inlet and outlet	0.096	0.092	1.04	0.094
72	P	30	F	21.4	-	Asymptomatic	-	Negative	Negative	No	0.066	0.066	1	0.063
73	S	35	F	21.6	-	Asymptomatic	-	Negative	Negative	No	0.078	0.078	1	0.076

S.No.	NAME	AGE (Yrs)	ɒgraphic Findings					Usg Impression	CTS status(USG)		MOTOR STUDIE						
			Lt outlet	I/O ratio	Flattening of nerve	Bowing of retinaculum	Anatomical variation		Right Hand	Left Hand	Rt Median nerve			Lt Median nerve			Rt
											DL	CMAP	NCV	DL	CMAP	NCV	DL
1	GK	47	0.063	1.1	Right outlet	No	No	R CTS	+	-	4.7	7.1	48.4	3.7	6.3	59.2	3
2	KK	46	0.101	0.9	B/l outlet	No	No	B/l CTS	+	+	5.3	9.4	59.7	4.9	4.3	57.5	2.6
3	HK	40	0.07	1	No	No	No	Normal	-	-	3.4	5.9	67.7	3.8	8.8	58.2	2.2
4	SK	47	0.099	0.82	Left outlet	No	No	L CTS	-	+	5.4	4.9	52.3	5.9	1.3	58	2.7
5	PK	38	0.09	0.9	No	No	No	R CTS	+	-	3.8	5.1	59.5	3	12.6	65.7	2.5
6	NK	32	0.081	1	Left outlet	No	No	L CTS	-	+	3.5	5.9	52.9	4.9	6.8	54.1	2.4
7	SB	44	0.121	1.06	B/l outlet	No	No	B/l CTS	+	+	9	12.2	51.1	8	7.8	50.5	2.4
8	SB	40	0.096	0.96	Left outlet	No	No	L CTS	-	+	2.5	13	54.1	3.5	9.4	59.7	2.7
9	RB	40	0.08	0.95	No	No	No	Normal	-	-	8.3	6.4	42.3	8.5	6.2	46.9	2
10	JC	31	0.133	0.83	No	No	No	B/l CTS	+	-	5	6.2	52.3	3.9	9.6	59.7	2
11	P	58	0.08	0.87	No	No	No	R CTS	+	-	3.2	7.6	54.8	3.4	6.9	54.5	2.8
12	MK	56	0.099	2.5	B/l inlet and outlet	Yes	No	B/l CTS	+	+	-	-	-	5.6	6.8	57.5	2.3
13	KS	46	0.085	0.85	No	No	No	Normal	-	-	4.2	10.5	50.5	5	7.9	52.6	3.3
14	GK	50	0.07	1	No	No	No	R CTS	+	-	6.1	7.9	55.4	3.5	10.6	63	2.9
15	PG	47	0.165	0.7	B/l inlet and outlet	No	No	B/l CTS	+	+	4.3	11.3	56.1	6.4	6.1	50.5	2.2
16	KP	45	0.073	1.11	No	No	No	Normal	-	-	4.2	8.3	55.4	6.6	3.2	56.8	2.5
17	JK	40	0.17	0.72	B/l inlet and outlet	Yes	No	B/l CTS	+	+	7.4	1.3	50	4.5	8	56.8	2.5
18	DK	48	0.08	1.05	No	No	No	Normal	-	-	7.8	8.1	56.1	7.1	6.6	54.8	2.2
19	DS	48	0.148	0.76	Left inlet and outlet	No	No	B/l CTS	+	+	3.4	10.7	54.3	5	6.9	52.3	1.8
20	JS	68	0.07	1.18	No	No	No	R CTS	+	-	3.9	7.5	46.9	3.2	8.4	46.9	2.5
21	N	42	0.124	0.81	B/l inlet and outlet	Yes	No	B/l CTS	+	+	4.5	7.3	51.2	4.1	13.6	62.9	1.9
22	R	38	0.067	0.83	No	No	No	Normal	-	-	3.9	8.5	47.4	3.4	9.1	45.5	1.8
23	JK	57	0.086	0.93	No	No	No	Normal	-	-	4.2	3	57.8	3.3	9.5	58.2	2.4
24	GK	57	0.11	0.86	B/l inlet and outlet	No	No	B/l CTS	+	+	5.6	4.4	50	4.6	6.4	66.7	2.1
25	VS	55	0.094	1.04	No	No	No	B/l CTS	+	+	3.3	6.6	45.8	3.6	7	46.9	2.5
26	V	38	0.119	1.25	B/l inlet and outlet	Yes	No	B/l CTS	+	+	5.5	12.2	56.1	4.1	10.6	68.2	2.2
27	SS	44	0.107	0.92	Right inlet	No	No	B/l CTS	+	+	4.9	5.7	54.1	4.6	4.5	45.1	2.6
28	LK	55	0.108	0.99	B/l inlet and outlet	Yes	No	B/l CTS	+	+	3.9	8.9	54.1	4.1	7.4	61.3	2.2
29	BJ	60	0.111	0.81	Right inlet	No	No	B/l CTS	+	+	4.8	7.2	47.1	4.7	8.1	49.5	2.9
30	JS	38	0.061	1.4	No	No	No	Normal	-	-	3.3	9	51.7	3.9	8.9	50.5	2.5
31	MA	45	0.096	1.16	B/l inlet	No	No	B/l CTS	+	+	-	-	-	6.2	7.4	45.5	2.2
32	RKT	35	0.073	1.27	No	No	No	B/l CTS	+	+	5	7	51.2	3.8	8.8	52.4	2.7
33	SK	32	0.073	0.99	No	No	No	R CTS	+	-	5.3	9.8	53.5	3.3	10.1	54.1	2.3
34	GK	42	0.093	1.12	Right outlet	Yes	No	B/l CTS	+	+	4.1	10.4	52.9	4.2	8.5	62.2	2
35	R	36	0.098	0.96	Right inlet	No	No	B/l CTS	+	+	4.9	8.7	50.8	4.9	11.9	55.4	3.1
36	RK	48	0.111	0.91	B/l inlet and outlet	Yes	No	B/l CTS	+	+	3.2	8.8	48.4	3.3	8	54.1	2.2
37	HK	47	0.11	0.91	Left outlet	No	No	B/l CTS	+	+	6.1	10.5	54.8	4.8	10.7	54.8	3
38	BK	50	0.077	0.91	No	No	No	Normal	-	-	11.7	1	29.8	7.1	3.9	49	2.6
39	NS	79	0.061	1.06	No	No	No	Normal	-	-	3.3	7.1	52.3	3.4	6.6	52.3	2.3
40	M	32	0.067	1.07	No	No	No	Normal	-	-	4.6	7.5	64.8	-	-	-	2.4
41	ND	53	0.105	0.88	B/l inlet and outlet	Yes	No	B/l CTS	+	+	5.2	7.6	55.4	5.4	7.7	55.4	2.3
42	KS	46	0.1	1.1	B/l inlet	Yes	No	B/l CTS	+	+	4.2	10.5	50.5	5	7.9	52.6	3.3
43	VS	74	0.065	1.03	No	No	No	Normal	-	-	3.5	5.3	60.5	3.5	5.4	62.2	2.6
44	GR	39	0.066	1.33	No	No	No	Normal	-	-	2.3	8.7	55.4	2.8	9.9	55.4	2.3
45	KS	50	0.072	0.89	No	No	No	Normal	-	-	2.9	9.9	56	2.9	8.1	61.8	2.1
46	BA	41	0.072	0.79	No	No	No	Normal	-	-	3	15.3	60.3	3.5	11.1	75.9	2.6
47	RK	37	0.082	1.15	No	No	No	L CTS	-	+	3.3	9.5	74.2	3.5	9	64.7	2.1
48	HK	28	0.07	0.86	No	No	No	Normal	-	-	3.2	8.4	56.8	3	9.6	58.2	2.5
49	RR	26	0.06	0.73	No	No	No	Normal	-	-	3.6	8.6	60.5	3.5	6.6	56.8	2.3
50	JK	50	0.055	0.89	No	No	No	Normal	-	-	3.9	6.9	56.8	3.6	7.1	57.5	2.5
51	KR	47	0.074	0.92	No	No	No	Normal	-	-	2.6	7.7	59	2.5	9	58.2	2.1
52	GD	49	0.049	1.14	No	No	No	Normal	-	-	3.1	11.5	64.8	3.1	7.6	64.8	2.2
53	VK	62	0.08	1.37	B/l inlet and outlet	Yes	No	B/l CTS	+	+	3.8	10	51.7	3.8	7.7	51.1	2.5
54	KK	29	0.06	0.98	No	No	No	Normal	-	-	2.8	7.1	48.9	2.9	9.9	53	2.5
55	P	23	0.048	1.25	No	No	No	Normal	-	-	3.8	4.6	46.9	3.1	13.9	53.5	2.9
56	SR	55	0.078	1.01	No	No	No	Normal	-	-	3.3	10.9	54.1	3.3	7.5	54.1	1.8
57	KK	51	0.092	0.88	No	Yes	No	Normal	-	-	2.9	9.8	58.2	3.7	8.6	45.1	2.5
58	NS	45	0.066	1.09	No	No	No	Normal	-	-	3.1	11.2	46.5	3.6	11.7	57.1	1.8
59	BK	36	0.063	1.13	No	No	No	Normal	-	-	3	14.2	53.2	2.8	13.9	55.3	2.6
60	BK	51	0.065	1.14	No	No	No	Normal	-	-	3.5	6.9	52.9	3.5	5.7	63	2.2
61	KS	52	0.066	1.03	No	No	No	Normal	-	-	3.1	8.5	48.5	3.4	9.2	46.2	2.8
62	JK	58	0.08	0.79	No	No	No	Normal	-	-	4	8.6	55.4	4	8.5	47.4	2.8
63	GK	45	0.09	0.88	No	No	No	Normal	-	-	2.9	11.7	56.1	3.1	12.1	61.3	1.6
64	P	26	0.056	1.12	No	No	No	Normal	-	-	2.8	12.1	61.3	2.3	11.3	66.7	1.9
65	K	54	0.11	0.92	No	No	No	B/l CTS	+	+	3.8	8.5	54.8	3.1	9.1	53.5	2.8
66	M	34	0.09	1.08	No	No	No	B/l CTS	+	+	3	13.4	58.2	3.1	12.7	59.7	2.1
67	RS	43	0.09	0.89	No	No	No	Normal	-	-	2.5	12.8	59	2.8	13.7	57.5	2.2
68	R	32	0.025	1.32	No	No	No	Normal	-	-	3.7	8.1	55.6	3.4	9.8	51	2.6
69	MK	52	0.078	0.96	No	No	No	Normal	-	-	3.4	5	52.9	3	5.1	50.5	2.5
70	MB	45	0.14	1.02	B/l inlet and outlet	Yes	No	B/l CTS	+	+	3.8	7.6	51.3	3.3	10.4	56.3	2.3
71	SC	71	0.095	0.88	No	No	No	B/l CTS	+	+	3.1	8.7	48.1	3.2	8.7	48.1	3.2
72	V	30	0.086	0.89	No	No	No	Normal	-	-	3	12.1	67.6	3	8.8	69.7	2.2
73	S	35	0.108	0.92	No	Yes	No	B/l CTS	+	+	3	10.9	50	3.5	10.1	63	2.3

S.No.	NAME	AGE (Yrs)	ɒgraphic Findings					Usg Impression	CTS status(USG)		MOTOR STUDIE						
			Lt outlet	I/O ratio	Flattening of nerve	Bowing of retinaculum	Anatomical variation		Right Hand	Left Hand	Rt Median nerve			Lt Median nerve			Rt
											DL	CMAP	NCV	DL	CMAP	NCV	DL
1	AK	58	0.061	1.16	No	No	No	-	-	-	-	-	-	-	-	-	-
2	A	30	0.073	1.1	No	No	No	-	-	-	-	-	-	-	-	-	-
3	A	40	0.069	0.87	No	No	No	-	-	-	-	-	-	-	-	-	-
4	B	34	0.062	0.87	No	No	No	-	-	-	-	-	-	-	-	-	-
5	S	36	0.065	1.18	No	No	No	-	-	-	-	-	-	-	-	-	-
6	D	32	0.075	0.97	No	No	No	-	-	-	-	-	-	-	-	-	-
7	S	42	0.071	1.07	No	No	No	-	-	-	-	-	-	-	-	-	-
8	D	25	0.084	0.55	No	No	No	-	-	-	-	-	-	-	-	-	-
9	E	25	0.056	1.09	No	No	No	-	-	-	-	-	-	-	-	-	-
10	G	32	0.064	1.06	No	No	No	-	-	-	-	-	-	-	-	-	-
11	H	44	0.08	0.79	No	No	No	-	-	-	-	-	-	-	-	-	-
12	H	40	0.073	0.81	No	No	No	-	-	-	-	-	-	-	-	-	-
13	H	40	0.079	0.75	No	No	No	-	-	-	-	-	-	-	-	-	-
14	H	31	0.075	0.8	No	No	No	-	-	-	-	-	-	-	-	-	-
15	J	58	0.054	1.07	No	No	No	-	-	-	-	-	-	-	-	-	-
16	MK	56	0.078	1	No	No	No	-	-	-	-	-	-	-	-	-	-
17	N	46	0.06	1.08	No	No	No	-	-	-	-	-	-	-	-	-	-
18	P	50	0.06	0.83	No	No	No	-	-	-	-	-	-	-	-	-	-
19	S	47	0.066	1.04	No	No	No	-	-	-	-	-	-	-	-	-	-
20	S	45	0.064	0.89	No	No	No	-	-	-	-	-	-	-	-	-	-
21	S	40	0.059	0.83	No	No	No	-	-	-	-	-	-	-	-	-	-
22	R	48	0.064	1.06	No	No	No	-	-	-	-	-	-	-	-	-	-
23	S	48	0.064	1.09	No	No	No	-	-	-	-	-	-	-	-	-	-
24	B	68	0.071	1.01	No	No	No	-	-	-	-	-	-	-	-	-	-
25	B	42	0.079	0.99	No	No	No	-	-	-	-	-	-	-	-	-	-
26	A	38	0.08	1.02	No	No	No	-	-	-	-	-	-	-	-	-	-
27	N	38	0.08	1.08	No	No	No	-	-	-	-	-	-	-	-	-	-
28	K	40	0.089	0.77	No	No	No	-	-	-	-	-	-	-	-	-	-
29	P	45	0.086	0.81	No	No	No	-	-	-	-	-	-	-	-	-	-
30	D	36	0.081	1.01	No	No	No	-	-	-	-	-	-	-	-	-	-
31	A	26	0.102	1	B/l inlet and outlet	Yes	No	-	-	-	-	-	-	-	-	-	-
32	A	28	0.084	0.93	No	No	No	-	-	-	-	-	-	-	-	-	-
33	P	56	0.064	0.89	No	No	No	-	-	-	-	-	-	-	-	-	-
34	J	70	0.059	0.83	No	No	No	-	-	-	-	-	-	-	-	-	-
35	P	47	0.064	1.06	No	No	No	-	-	-	-	-	-	-	-	-	-
36	R	50	0.064	1.09	No	No	No	-	-	-	-	-	-	-	-	-	-
37	GK	79	0.071	1.01	No	No	No	-	-	-	-	-	-	-	-	-	-
38	S	32	0.079	0.99	No	No	No	-	-	-	-	-	-	-	-	-	-
39	S	53	0.08	1.02	No	No	No	-	-	-	-	-	-	-	-	-	-
40	M	46	0.064	1.06	No	No	No	-	-	-	-	-	-	-	-	-	-
41	G	74	0.064	1.09	No	No	No	-	-	-	-	-	-	-	-	-	-
42	SD	54	0.071	1.01	No	No	No	-	-	-	-	-	-	-	-	-	-
43	D	52	0.079	0.99	No	No	No	-	-	-	-	-	-	-	-	-	-
44	P	39	0.075	1.01	No	No	No	-	-	-	-	-	-	-	-	-	-
45	JC	50	0.072	0.99	No	No	No	-	-	-	-	-	-	-	-	-	-
46	K	41	0.059	0.83	No	No	No	-	-	-	-	-	-	-	-	-	-
47	M	37	0.064	1.06	No	No	No	-	-	-	-	-	-	-	-	-	-
48	D	28	0.064	1.09	No	No	No	-	-	-	-	-	-	-	-	-	-
49	Y	26	0.071	1.01	No	No	No	-	-	-	-	-	-	-	-	-	-
50	D	50	0.065	1	No	No	No	-	-	-	-	-	-	-	-	-	-
51	K	47	0.064	1	No	No	No	-	-	-	-	-	-	-	-	-	-
52	U	49	0.09	1	B/l inlet and outlet	Yes	No	-	-	-	-	-	-	-	-	-	-
53	SK	62	0.056	1.09	No	No	No	-	-	-	-	-	-	-	-	-	-
54	A	29	0.064	1.06	No	No	No	-	-	-	-	-	-	-	-	-	-
55	SJ	23	0.08	0.79	No	No	No	-	-	-	-	-	-	-	-	-	-
56	A	55	0.073	0.81	No	No	No	-	-	-	-	-	-	-	-	-	-
57	G	51	0.079	0.75	No	No	No	-	-	-	-	-	-	-	-	-	-
58	S	45	0.075	0.8	No	No	No	-	-	-	-	-	-	-	-	-	-
59	RK	36	0.054	1.07	No	No	No	-	-	-	-	-	-	-	-	-	-
60	R	51	0.078	1	No	No	No	-	-	-	-	-	-	-	-	-	-
61	P	52	0.06	1.08	No	No	No	-	-	-	-	-	-	-	-	-	-
62	J	58	0.06	0.83	No	No	No	-	-	-	-	-	-	-	-	-	-
63	N	45	0.066	1.04	No	No	No	-	-	-	-	-	-	-	-	-	-
64	N	26	0.08	0.79	No	No	No	-	-	-	-	-	-	-	-	-	-
65	M	54	0.073	0.81	No	No	No	-	-	-	-	-	-	-	-	-	-
66	R	34	0.079	0.75	No	No	No	-	-	-	-	-	-	-	-	-	-
67	S	43	0.056	1.09	No	No	No	-	-	-	-	-	-	-	-	-	-
68	M	32	0.064	1.06	No	No	No	-	-	-	-	-	-	-	-	-	-
69	A	52	0.08	0.79	No	No	No	-	-	-	-	-	-	-	-	-	-
70	D	45	0.073	0.81	No	No	No	-	-	-	-	-	-	-	-	-	-
71	JS	71	0.093	1.01	B/l inlet and outlet	Yes	No	-	-	-	-	-	-	-	-	-	-
72	P	30	0.063	1	No	No	No	-	-	-	-	-	-	-	-	-	-
73	S	35	0.076	1	No	No	No	-	-	-	-	-	-	-	-	-	-

S.No.	NAME	AGE (Yrs)	NCS																	CTS status (NCS)	
			S					SENSORY STUDIES													
			Ulnar nerve		Lt Ulnar nerve			Rt Median nerve			Lt Median nerve			Rt Ulnar nerve			Lt Ulnar nerve			NCS RESULT	
			CMAP	NCV	DL	CMAP	DL	DL	SNAP	NCV	DL	SNAP	NCV	DL	SNAP	NCV	DL	SNAP	NCV		Right hand	Left hand
1	GK	47	9.6	56.8	2.8	9.2	56.4	4.7	43	38.3	3.6	71.7	50.7	3.3	41.7	56.9	3.5	43.5	55.6	R CTS	+	-
2	KK	46	11.1	71.6	3.2	9.8	68.6	4.8	21.3	36.8	4.4	18.1	39.8	2.7	29.3	68.6	2.9	20.1	61.4	B/l CTS	+	+
3	HK	40	9.1	64.8	2.1	7.9	67.6	3.6	13.3	50	3.7	28.7	52.6	2.7	25.2	66.7	2.7	24	69.3	B/l CTS	+	+
4	SK	47	11.4	68.6	3	10.9	65.8	5.5	11.1	36.1	5.2	20.8	36.1	3	22.9	64.8	2.8	34	66	B/l CTS	+	+
5	PK	38	7.3	69.7	2.5	8.3	68.7	3.8	43.9	48.3	3.6	24	45.8	2.9	38.8	65.4	2.8	44.7	68	R CTS	+	-
6	NK	32	8.3	69.7	2.3	7.4	68.6	3.6	61.8	52.2	4.5	55.8	40.7	2.7	69.3	68	3.2	54.5	58.3	L CTS	-	+
7	SB	44	11.2	52.2	2.4	10.5	62.3	-	-	-	6.8	8.2	24.3	2.7	38.8	69.3	2.9	44.9	63.6	B/l CTS	+	+
8	SB	40	9.2	66.7	2.6	9.4	70.6	3.3	81.7	58.8	3.8	71.6	49.3	3.2	51.9	62.5	3.5	48.5	51.1	L CTS	-	+
9	RB	40	8.9	57.5	2.4	8.4	69.7	8.7	3.5	19.5	9.2	4.5	19.5	2.6	51.6	69.3	2.5	61.4	74.5	B/l CTS	+	+
10	JC	31	8.1	57.8	2.1	7.1	65.8	5	12.7	32.3	3.4	36.4	51.9	2.6	36.3	67.3	2.4	41.5	74.5	R CTS	+	-
11	P	58	7.6	57.1	2.6	7.4	44	3.4	18.7	53.4	3.9	16.1	46.1	3.5	23.3	51.5	3.3	19.6	51.5	L CTS	-	+
12	MK	56	11.3	64	2.5	10.8	53.9	-	-	-	5.1	8.5	33.2	2.4	25.9	80.5	2.7	26.5	76.1	B/l CTS	+	+
13	KS	46	10.8	51.6	4	9.3	58.5	4.2	35.3	46.1	4.3	26.7	43.5	3.8	12.7	47.3	3.9	28.9	46.1	B/l CTS	+	+
14	GK	50	9.7	109	2.6	11	98	4.6	4.2	21.3	3.6	23.1	49.6	2	84.2	46.4	2.7	29.8	68.6	R CTS	+	-
15	PG	47	9.4	57.8	2.2	9	59.3	4.1	19.7	43.2	6	4.5	30	2.5	25.8	68.8	2	40.9	55.1	B/l CTS	+	+
16	KP	45	11.3	64.9	2.1	8.3	61.5	4.4	24.8	40.5	-	-	-	3.2	33.8	57.9	3	23.4	61.4	B/l CTS	+	+
17	JK	40	11.5	69.6	2.2	10.5	64	6.8	9.7	27	4.3	20.7	42.2	2.6	33	69.3	2.8	32.1	63.6	B/l CTS	+	+
18	DK	48	10.2	77.4	2.1	10.5	70.6	-	-	-	-	-	-	2.5	26.8	72.2	2.7	29.2	65.4	B/l CTS	+	+
19	DS	48	6.9	62.2	2.7	8.7	67.6	3.1	28.8	56.9	-	-	-	2.6	27.9	66.7	2.7	25.5	64.2	L CTS	-	+
20	JS	68	7.7	49.5	2.5	8	57.1	4	12	45.5	3.6	14	47.9	3.3	23.1	61.4	3	13.2	68.6	R CTS	+	-
21	N	42	12.9	60.3	2.2	14.3	62	5	16.4	36.6	3.9	40.7	45.5	2.4	72.1	76.1	2.6	78.8	75.3	B/l CTS	+	+
22	R	38	9.5	56.5	1.7	9.5	57.1	4	28.1	46.1	3.6	34.8	51.1	2.7	35.6	75.3	2.7	40.5	68	R CTS	+	-
23	JK	57	11	59.3	1.8	9.2	58.5	4.7	5.2	38.7	3.6	27.6	49	2.7	20.3	66.7	2.6	22.2	68.6	R CTS	+	-
24	GK	57	10.3	70.6	2.4	9.8	75	4.5	13.4	38	5.3	7	35.4	2.7	28.5	66	2.8	22.5	63.6	B/l CTS	+	+
25	VS	55	5.6	50.5	2.8	6.6	55.8	3.6	11.9	53	3.6	15.4	47	2.8	15.1	64.2	3.1	14.9	67.3	B/L CTS	+	+
26	V	38	13.8	66.7	2.2	9.5	69.6	5.5	8.6	36.3	4.3	38.9	40	2.8	19.6	64.8	2.8	19.3	64.2	B/L CTS	+	+
27	SS	44	6.6	71.6	2.4	6	71.6	4.6	13.2	46.4	4.9	13.3	34.7	2.7	21.6	66.7	2.8	21.9	64.8	B/L CTS	+	+
28	LK	55	9.4	69.6	2.1	7.9	72.7	3.7	60.6	49	3.9	42	49	2.5	48.5	76.1	3	18.4	73.7	B/L CTS	+	+
29	BJ	60	6.6	44.2	2.6	6.1	53.2	4.8	13.2	37	5.1	14.5	35.5	3.3	18.9	62.5	3.2	16.1	56.5	B/L CTS	+	+
30	JS	38	6.9	51.1	3.3	9	66.7	3.5	33.1	52.2	4	32.2	47.3	3.2	30.3	60.3	3.4	33.1	56.9	L CTS	-	+
31	MA	45	11.1	59.3	2.4	10.3	61.5	-	-	-	6.7	15.4	33.8	2.6	37.7	75.3	2.7	39.5	81.4	B/l CTS	+	+
32	RKT	35	11.2	72.1	2.8	9.5	75.9	4.8	20.2	37	4.5	37.5	40.2	2.8	37.7	88.6	2.7	48.6	73.7	B/L CTS	+	+
33	SK	32	12.5	54.5	2.1	12.7	75	4	25.7	44.3	3.2	67.4	55.1	2.8	53.7	64.8	2.8	55.2	67.3	R CTS	+	-
34	GK	42	10.7	69.6	2.5	11.2	92.3	4.3	32.8	42.9	4	38.6	46.1	2.5	65.4	74.5	2.5	66.4	74.5	B/L CTS	+	+
35	R	36	13.8	56.5	2.4	11	61.5	5	19.9	35.2	5.5	20.3	33.8	3.1	48.1	62.5	3.1	41.4	67.3	B/l CTS	+	+
36	RK	48	8.7	59.3	2.5	8.2	71.6	4.2	45.8	44.9	3.7	48.1	52.2	2.7	40.5	70.7	3.1	45.7	63.6	B/l CTS	+	+
37	HK	47	13.7	53.5	3.3	10.9	55.2	6.5	29.7	28.6	4.9	52.1	39.3	3.5	36.5	53	3.6	33.4	52.2	B/l CTS	+	+
38	BK	50	9.5	64.9	2.6	9.4	61.7	-	-	-	5.9	4.8	28.9	2.9	41.9	64.8	3	24.2	63.6	B/l CTS	+	+
39	NS	79	8.9	44.4	2.6	6.8	55.8	4.1	12.7	43.2	3.6	32.8	53	2.9	12.9	64.2	3.7	14.2	52.6	R CTS	+	-
40	M	32	10.6	76.2	2.1	10.2	73.8	4	27	47.3	3.5	10.5	31.8	2.6	31.2	70.7	2.3	27.1	76.9	R CTS	+	-
41	ND	53	6.7	62.3	2.9	5.9	73.8	4	31.6	46.1	4.5	32.2	40.2	2.5	53.2	72.1	2.6	50.7	70	B/l CTS	+	+
42	KS	46	10.8	51.6	4	9.3	58.5	4.2	35.3	46.1	4.3	26.7	43.5	3.8	12.7	47.3	3.9	28.9	46.1	B/l CTS	+	+
43	VS	74	8.7	53.3	2.3	8.3	66.7	3.3	30.1	53.8	3.2	40.5	59.3	2.8	21.4	65.4	2.7	20.1	68	B/l CTS	+	+
44	GR	39	7.1	75	2.1	8.3	64	3	40.1	62.5	2.8	47.5	61.4	2.8	25.5	66	2.6	32.5	72.9	Normal	-	-
45	KS	50	8.6	65.8	2.2	6.6	69.6	2.9	67.4	63.6	2.9	63.4	61.4	2.7	53.2	70.7	2.7	51.1	66.7	Normal	-	-
46	BA	41	8.6	63.9	2.3	7.8	59.7	3.1	85.5	64.2	3.1	79.5	59.3	2.9	53.4	61.4	2.9	62.2	65.4	Normal	-	-
47	RK	37	11	81.4	2	12.5	78.7	3.1	18.5	59.8	3.3	25.3	51.5	2.3	22.6	83.3	2.5	27.8	72.9	Normal	-	-
48	HK	28	11.6	62.3	2.4	10.2	69.6	3.2	105.4	65.4	3.2	101.4	57.7	2.9	85.5	66	2.7	101.1	71.4	Normal	-	-
49	RR	26	10.1	81.4	2.1	11.3	66.7	2.9	47.5	62.5	3	37.7	63.6	2.5	49.1	72.9	2.7	55.6	72.2	Normal	-	-
50	JK	50	7.2	60	2.5	9.3	68.7	3.5	36.2	54.7	3.5	36.5	53	2.7	28.5	69.3	2.7	28.5	69.3	Normal	-	-
51	KR	47	7.9	60	2.2	8.4	63.2	2.7	43.7	66.7	2.7	52.8	71.4	2.3	24.6	77.8	2.5	29	75.3	Normal	-	-
52	GD	49	12.1	70.6	2.4	9.2	69.6	3.2	34.5	64.2	3.4	44.8	60.3	3.3	30.4	59.3	2.9	35	70.7	Normal	-	-
53	VK	62	7.9	54.5	2.6	8.7	52.7	3.5	37.6	50.7	3.5	53.7	50	2.7	39.5	65.4	2.7	42.2	66.7	Normal	-	-
54	KK	29	8.2	62.2	2.5	9	64.8	3.1	61.7	60.3	3	52.5	58.8	3	53.7	62.5	2.7	67.7	68	Normal	-	-
55	P	23	8.6	63.2	3	12.2	65.8	3.4	54.4	52.6	3.5	45.1	51.5	3.7	11.1	48.6	3.6	46.5	49	Normal	-	-
56	SR	55	6.2	56.5	2	7.2	60.8	3.4	45.4	54.7	3.4	50.1	57.9	2.9	40.6	64.8	2.8	45.5	70.7	Normal	-	-
57	KK	51	7.5	73.8	1.9	6.6	64.9	3.1	34.1	60.3	3.4	31.8	55.1	3	21.5	63.6	2.9	31.9	66	Normal	-	-
58	NS	45	9.1	49	2.7	12.1	43.8	3.1	32.4	54.7	3.2	24.9	55.1	2.9	28	69.3	3	29.4	60.9	Normal	-	-
59	BK	36	14.2	66.7	2.5	13.9	66.7	3.1	50.5	60.9	3	56	66.7	2.8	52.5	70	3	67.8	66.7	Normal	-	-
60	BK	51	9.5	64	2.3	8.4	61.5	3.3	30.8	56.9	3.3	37.3	53.4	2.7	39.3	68	2.7	27.8	68	Normal	-	-
61	KS	52	7.6	49.5	2.7	8	59.8	3.2	28.3	60.9	3.1	30.7	59.3	2.8	27.7	72.2	3.1	32.2	56.9	Normal	-	-
62	JK	58	11.7	56.5	2.9	10	56.5	3.3	33.1	53.4	3.6	38.7	50.7	2.8	35.3	70	3	36.7	59.3	Normal	-	-
63	GK	45	9.9	61.5	2.2	9.1	64.9	3.2	31.7	54.3	3.1	32.5	58.8	2.6	35.5	72.9	2.6	30.4	70.7	Normal	-	-
64	P	26	9.7	70.6	1.9	8.8	69.6	2.7	54.8	72.2	3	64.7	61.9	2.4	63.9	77.8	3.9	65.3	63.6	Normal	-	-
65	K	54	8.5	70.6	2.2	9.3	66.7	3.1	40.5	57.4	3.2	39.9	58.8	2.6	46.6	76.9	2.9	45	62.5	Normal	-	-
66	M	34	11.4	64.9	2.4	9.8	69.6	3	42.2	60.3	3	45.1	64.2	2.6	22.4	72.9	2.5	34.1	78.7	Normal	-	-
67	RS	43	9.1	70.6	2	10.7	66.7	2.9	35.4	67.3	2.7	37.8	68	2.4	32.7	76.9	2.6	39.5	70.6	Normal	-	-
68	R	32	10.1	63.4	2.6	12.7	54.7	3.6	46.5	53.8	3.5	66.6	56.5	3.5	61.2	56.5	3.4	59.1	54.3	Normal	-	-
69	MK	52	9.7	57.1	2.8	9.4	71.6	3.5	29.5	50.7	3.5	45.1	51.5	2.9	34.2	65.4	3.3	36.6	61.4	Normal	-	-
70	MB	45	11	60	2	10.9	61.8	3.5	44	-	3.5	46.7	-	2.5	42.4	-	2.5	54.4	-	Normal	-	-
71	SC	71	6.5	51.5	2.3	6.2	57.1	3.5	19.1	55.6	3.5	22.8	52.2	3.4	18.3	54.3	3.1	16.8	57.9	Normal	-	-
72	V	30	10.7	64.9	2.6	9.3	80	3	85.9	67.3	3	64.9	63.1	2.7	66.3	75.3	2.9	80.7	65.4	Normal	-	-
73	S	35	12.5	53.9	2.4	12.7	67.6	3	34.4	58.8	3.3	48.5	55.1	2.7	28.5	66	2.8	31.2	66.7	Normal	-	-

S.No.	NAME	AGE (Yrs)	NCS																		CTS status (NCS)	
			S						SENSORY STUDIES														
			Ulnar nerve		Lt Ulnar nerve			Rt Median nerve			Lt Median nerve			Rt Ulnar nerve			Lt Ulnar nerve			NCS RESULT		
			CMAP	NCV	DL	CMAP	DL	DL	SNAP	NCV	DL	SNAP	NCV	DL	SNAP	NCV	DL	SNAP	NCV		Right hand	Left hand
1	AK	58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	A	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	A	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	B	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	S	36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	D	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	S	42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	D	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	E	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	G	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	H	44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	H	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	H	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	H	31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	J	58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	MK	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	N	46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	P	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	S	47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	S	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	S	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	R	48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	S	48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	B	68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	B	42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	A	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	N	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	K	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	P	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	D	36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	A	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	A	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	P	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	J	70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35	P	47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36	R	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	GK	79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	S	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	S	53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	M	46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	G	74	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42	SD	54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
43	D	52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	P	39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	JC	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	K	41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47	M	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	D	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49	Y	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	D	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
51	K	47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	U	49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
53	SK	62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54	A	29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55	SJ	23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56	A	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
57	G	51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58	S	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
59	RK	36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	R	51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
61	P	52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62	J	58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
63	N	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
64	N	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
65	M	54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
66	R	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
67	S	43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
68	M	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
69	A	52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70	D	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
71	JS	71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
72	P	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
73	S	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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The Principal,
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Subject: **Approval of Plan of Thesis.**

This is to inform you that the Faculty of Medical Sciences in its meeting held on 29.05.2019 has approved the plan of thesis of **Ekamjot Singh**, a student of your college for **MD Radio-Diagnosis** along with the names of Supervisor/Co-Supervisor as under:-

Topic Plan of Thesis

Role of ultrasound in the diagnosis of carpal tunnel syndrome

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The student has to submit the four copies of thesis (along with PDF format) , to the Controller of Examinations, BFUHS, Faridkot, at least six months before the commencement of theory examination, if he/she is otherwise eligible to take the examination. He /She must directed to attach a photocopy of this letter with the forwarding letter while submitting thesis to the University along with the letter of approval of University for change of supervisor/Co-Supervisor, change of topic,(if any).

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Controller of Examinations

Note :

1. *If any discrepancy found regarding topic of thesis or Supervisor/Co-Supervisor, inform undersigned within one month after issue of this letter.*
2. *The student may submit the thesis as per the schedule already conveyed i.e for May/June examination 30th Nov of the preceding the year of examination and for Nov/Dec examinations 31st May of the year of examination.*

ROLE OF ULTRASOUND IN THE DIAGNOSIS OF CARPAL TUNNEL SYNDROME

THESIS PROPOSAL

FOR APPROVAL OF SUBJECT OF THESIS TO BE SUBMITTED

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

Doctor of Medicine
in

RADIODIAGNOSIS

OF THE

BABA FARID UNIVERSITY OF HEALTH SCIENCES
FARIDKOT

December, 2018

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ABSTRACT OF PLAN OF THESIS

Title	ROLE OF ULTRASOUND IN THE DIAGNOSIS OF CARPAL TUNNEL SYNDROME
For the degree of	M.D RADIODIAGNOSIS
Name of the candidate	Dr Ekamjot Singh
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Introduction: Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy of upper limb owing to compression of median nerve. Diagnosis of CTS is usually based on a combination of clinical signs and nerve conduction studies (NCS).NCS assesses the function of the median nerve, indicate the level of lesion,define severity of CTS, and is currently used to confirm the diagnosis, however false negative rates of upto 34% have been reported with NCS.High resolution sonography has emerged as feasible, noninvasive imaging tool for evaluating median nerve in the carpal tunnel. It permits perception of nerve compression characteristics, including altered signal, increased cross sectional area, flattening of the nerve and bowing of the flexor retinaculum.

The purpose of this study is to determine if ultrasound can be used as an alternative to diagnose CTS.

Aims of Study:

1. To assess role of ultrasound in the diagnosis of carpal tunnel syndrome.
2. To correlate ultrasound diagnosis with nerve conduction studies, considering nerve conduction studies as gold standard for diagnosis of carpal tunnel syndrome.
3. To compare ultrasound parameters of median nerve in cases of carpal tunnel syndrome with an equal number of age matched healthy controls.

Material & Methods: All patients with clinical diagnosis of carpal tunnel syndrome, referred for high frequency ultrasound of median nerve to the Department of Radiodiagnosis at DMCH, Ludhiana, over a period of one year will be included in the study.

Clinical Significance: Because of its higher patient acceptability, lower cost, capability to assess carpal tunnel anatomy and therapeutic value of guiding steroid injections, ultrasound can be used as a first modality to diagnose carpal tunnel syndrome.

Keywords: Median Nerve, Sonography, Nerve Conduction studies.

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CERTIFICATE OF FACILITIES AVAILABLE

This is to certify that the facilities for work on the subject of thesis titled **"ROLE OF ULTRASOUND IN THE DIAGNOSIS OF CARPAL TUNNEL SYNDROME"** exist in the Department of Radiodiagnosis, DMC&H, Ludhiana and will be provided to the candidate. We will see that the data being included in the thesis is genuine and is collected by the candidate himself under our supervision and guidance.

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PROFORMA FOR REGISTRATION OF SUBJECT FOR DISSERTATION

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5	TITLE OF THE TOPIC	ROLE OF ULTRASOUND IN THE DIAGNOSIS OF CARPAL TUNNEL SYNDROME

6. BRIEF RESUME OF THE INTENDED WORK

6.1 NEED FOR THE STUDY

CTS is a common problem with an estimated annual incidence rate of 0.5-5.1 per 1000[1,2] and is a major cause of loss of working days for workers, especially in hand intensive occupations.[1,3,4] Current trends of increase in its risk factors will likely result in an increased prevalence of CTS. Diabetes, obesity, an increasing life span and occupational risks are several of the contributing factors expected to increase the incidence rate.[5-7] As these trends increase so too will the need for a reliable, non-invasive method of assessing and diagnosing CTS. Diagnosis of CTS often relies on a clinical diagnosis based on patient history, specific symptoms, and physical tests (Phalen's, Reverse Phalen's, Tinel, carpal tunnel compression, hand elevation tests).However atypical cases are often missed clinically.

More commonly, a clinical diagnosis of CTS is followed by confirmatory nerve conduction studies. Nerve conduction studies evaluate the function of the median nerve, measuring the sensory and motor latencies, amplitudes, and velocities of the median nerve.[8] However, nerve conduction studies are invasive, uncomfortable, time consuming, and costly. Additionally, high rates of false-positives, false-negatives and a wide range of sensitivities have been reported with NCS.[9-10]

Sonography is widely available and non-invasive investigation which is cost-efficient, portable, and well tolerated by patients. The non-invasive nature and lack of radiation makes sonography an ideal modality for repeat examinations. Ultrasound has shown to be a useful diagnostic tool for CTS, providing information about median nerve anatomy and surrounding structures.

Evaluation of the Cross sectional area (CSA) of the median nerve, its echogenicity, vascularisation, and bowing of flexor retinaculum have been reported as beneficial parameters for sonographically assessing CTS.[11-14] It has been proposed that sonography may replace NCS as a first-line test to confirm clinically diagnosed CTS, potentially eliminating the need for NCS in over 50% of the patients.[15,16]

Evaluating multiple variables, both sonographic and clinical, may provide a more inclusive assessment of physiologic changes in the median nerve.

It is now time to consider a new paradigm in the diagnosis and monitoring of CTS. After an initial clinical work up of CTS, ultrasound can be used to assess the anatomy of the nerve and surrounding structures and to rule out anatomical variants. Patients with a negative sonography but symptomatic or those with atypical symptoms or signs or those who fail to respond to treatment could be subjected to nerve conduction studies.

Ultrasound of the median nerve in the carpal tunnel is a relatively quick test that is acceptable to the patient and can be performed on the outpatient clinic at initial assessment. In certain patients this could then be followed by US-guided steroid injection at the same visit.

6.2 REVIEW OF LITERATURE

Many studies have been published till date which evaluate the role of ultrasound as an alternative diagnostic modality in carpal tunnel syndrome.

Buchberger et al in 1992 evaluated patients with clinical symptoms of carpal tunnel syndrome and with abnormal nerve conduction studies with real-time sonography and MR imaging. The sonograms and MR images were evaluated quantitatively by two unbiased observers with regard to the size and shape of the median nerve and the palmar bowing of the flexor retinaculum. A test was used to compare these data with those from previous sonographic studies. The relative accuracies of different diagnostic criteria for the diagnosis of carpal tunnel syndrome were assessed by using receiver-operating-characteristic analytical techniques. Characteristic findings in patients with carpal tunnel syndrome included swelling of the median nerve in the proximal part of the carpal tunnel, flattening of the median nerve in the distal part of the carpal tunnel and increased palmar bowing of the flexor retinaculum. Comparison with the data of normal wrists proved that these findings were significant (p less than .01 to p less than .001). Receiver-operating-characteristic analysis showed that the discrimination between wrists in normal subjects and in patients with carpal tunnel syndrome achieved with each of the three diagnostic criteria was not significantly different. Measurements of the size and flattening of the median nerve obtained from sonograms were similar to those on MR images, whereas sonography was less accurate for measuring the palmar bowing of the flexor retinaculum.[14]

El Miedany et al (2004), in his study, concluded that High-frequency Ultrasound examination of the median nerve and measurement of its cross-sectional area should be strongly considered as a new alternative diagnostic modality for the evaluation of CTS. In addition to being of high diagnostic accuracy it is able to define the cause of nerve compression and aids treatment planning.It also provides a reliable method for following the response to therapy.[17]

Ziswiler et al in 2005 conducted a prospective study of 110 wrists in 74 consecutive patients with suspected CTS who had been referred to a tertiary care center and determined the largest cross-sectional area of the median nerve at the carpal tunnel. Because of the lack of a universally accepted reference standard, he first examined the association of sonography with nerve conduction and then compared sonography with a reference standard based on the combination of nerve conduction studies and signs and symptoms. Sonography and reference standard tests were performed independently and interpreted under blinded conditions. Based on a fitted receiver operating characteristic curve, estimated likelihood ratios (LRs) and posttest probabilities for different cutoffs. He found that there was a high concordance between sonography and nerve conduction. Based on the combined reference standard, a cutoff of 10 mm2 resulted in approximately equal sensitivity and specificity, but only moderate LRs. A cutoff of <8 mm2 had satisfactory power to rule out CTS: the fitted-negative LR was 0.13. Conversely, a cutoff of > or =12 mm2 had excellent power to rule in CTS, with a fitted-positive LR of 19.9. For nerves > or =12 mm2 and a pretest probability

of 70% expected in patients with suspected CTS in tertiary care, they found a post-test probability of CTS of 98%.[18]

Tengfei et al in 2015 conducted a study in patients with clinical and electrodiagnostic evidence of CTS and 44 healthy volunteers were also examined with ultrasonography. The cross-sectional area (CSA) of the median nerve was measured at the carpal tunnel inlet (the level of scaphoid-pisiform) and outlet (the level of the hook of the hamate), and the IOR(Inlet/Outlet Ratio) was calculated for each wrist. Ultrasonography and electrodiagnostic tests were performed under blinded conditions. Electrodiagnostic testing combined with clinical symptoms were considered to be the gold standard test. Receiver operating characteristic (ROC) curves were used to evaluate the diagnostic value between the inlet CSA and IOR. The mean inlet CSA was 8.7 mm2 in healthy controls and 14.6mm2 in CTS group ($P<0.001$). The mean IOR in healthy volunteers (1.0) was smaller than that in patients (1.6, $P<0.001$). Receiver operating characteristic analysis revealed a diagnostic advantage to using the IOR rather than the inlet CSA ($P<0.01$). An IOR cutoff value of ≥ 1.3 would yield 93% specificity and 91% sensitivity in the diagnosis of CTS. He concluded that IOR of median nerve area promises to be an effective means in the diagnosis of CTS.[11]

Da Sol Ha et al (2017) conducted study on 54 female patients of clinically diagnosed CTS and correlated the severity of CTS according to electrodiagnostic studies and proximal Cross Sectional Area(CSA) on ultrasound. They concluded that the severity by electrodiagnostic results

statistically correlated to the proximal cross-sectional area of the median nerve.[19]

Mallouhi et al (2006) in a study examined total of 206 wrists in 151 patients with a clinical suspicion of carpal tunnel syndrome with high-resolution sonography using a 7–15-MHz linear array transducer. The presence of median nerve swelling, edema, and flattening and increased bowing of the flexor retinaculum was evaluated with gray-scale sonography and the presence of nerve hypervascularization was evaluated with color Doppler sonography. Sensitivity and specificity were calculated for each sonographic feature in comparison with nerve conduction studies as the standard of reference. Multivariate logistic regression analysis was used to determine variables predictive of carpal tunnel syndrome. Carpal tunnel syndrome was confirmed in 172 wrists at nerve conduction studies. A median nerve cross-sectional area of at least 0.11 cm2 was calculated as a definition of median nerve swelling. In comparison with nerve conduction studies, nerve swelling showed the highest accuracy (91%) among gray-scale sonography criteria, and the presence of intraneural hypervascularization showed the highest accuracy (95%) among all sonography criteria. Logistic regression analysis showed that nerve hypervascularization was the only variable that independently predicted median nerve entrapment (odds ratio, 16.4; 95% confidence interval, 8.7-31.1; p <0.001). Further, he concluded that Color Doppler sonography is more accurate than gray-scale sonography for characterizing median nerve involvement in patients with suspected CTS.[20]

6.3 AIMS AND OBJECTIVES OF THE STUDY

- To assess role of ultrasound in the diagnosis of carpal tunnel syndrome.
- To correlate ultrasound diagnosis with nerve conduction studies, considering nerve conduction studies as gold standard for diagnosis of carpal tunnel syndrome.
- To compare ultrasound parameters of median nerve in cases of carpal tunnel syndrome with an equal number of age matched healthy controls.

7. MATERIALS AND METHODS

A prospective study in all clinically diagnosed cases of CTS, referred for ultrasound assessment of median nerve to the department of Radiodiagnosis at DMCH Ludhiana, will be conducted over a period of one year on LOGIQ E9 or Phillips IU22 machine using a 6-15 Mhz linear probe.

Written informed consent will taken from each patient in his/her vernacular language before making him/her part of the study and relevant history will be elicited from each patient.

Sonographic evaluation

The median nerve will be imaged at the wrist joint in transverse and longitudinal planes using high-resolution real-time sonography. Individuals will be positioned with forearm supine, elbow semi-flexed, and the fingers and wrist in a neutral position.

Asymptomatic wrist of the same patient and healthy volunteer age matched controls will also be imaged on ultrasound and all the parameters will be measured and recorded as per proforma.

7.1 Source of Data

The study will be conducted on all patients of any age group with clinical diagnosis of Carpal tunnel Syndrome referred from indoor or outdoor patient department to the department of Radiodiagnosis, DMCH for ultrasound evaluation.

7.2 METHOD OF COLLECTION OF DATA

A prospective longitudinal study in clinically suspected cases of CTS, referred for sonographic assessment to Department of Radiodiagnosis,DMCH

Ludhiana, will be conducted over a period of one year on LOGIQ E9 / Phillips IU22 machine using a 6-15 Mhz linear probe.

INCLUSION CRITERIA

Patient with clinical diagnosis of Carpal Tunnel Syndrome.

EXCLUSION CRITERIA-

1) Patients with fracture of carpal bones or carpo-metacarpal dislocations.

2) Patients with distorted anatomy at wrist joint and those who underwent surgery around the wrist.

3) Patients with Bifid median nerve.

4) Patients who didn't consent to be part of the study.

DURATION OF STUDY

The study will be conducted over a period of one year.

OUTCOME

The study will be conducted over one year period to evaluate the efficacy of high resolution ultrasonography in diagnosis of CTS and its correlation with findings of nerve conduction studies.

STATISTICAL ANALYSIS: Data will be described in terms of range; mean ±standard deviation (± SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. Sensitivity, specificity, positive and negative predictive values and accuracy of each method and its confidence interval (95% CI) will also be determined, besides the Youden index (probability of correct classification) and determining the area under the ROC curve. A probability value (*p* value) less than 0.05 will be considered statistically significant.All statistical calculations will be done using SPSS

(Statistical Package for the Social Science) SPSS 21 version statistical program for Microsoft Windows.

7.3 DOES THE STUDY REQUIRE ANY INVESTIGATIONS OR INTERVENTIONS TO BE CONDUCTED ON PATIENTS OR OTHER HUMANS OR ANIMALS? IF SO, PLEASE DESCRIBE BRIEFLY.

The study requires High frequency ultrasound to be done in clinically suspected patients of CTS.

However the study does not require any intervention to be conducted on patients.

7.4 HAS ETHICAL CLEARANCE BEEN OBTAINED FROM YOUR INSTITUTION IN CASE OF 7.3?

Attached herewith

8. LIST OF REFERENCES

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INFORMED PATIENT CONSENT

Date: _____

I.....D/o, W/o, S/o.....

.....am willing to participate in the study **"ROLE OF ULTRASOUND IN THE DIAGNOSIS OF CARPAL TUNNEL SYNDROME"** The procedure with its complications has been explained to me in local vernacular language. I have fully understood that no special tests and extra expenditure in any form, merely for the purpose of thesis is being carried out. I am free to opt out the study any time without assigning any reason.

.....
Signature of the Witness

Name:

.....
Signature of the patient

Signature of Candidate

Signature of Supervisor

मरीज अनुमति फार्म

तिथि _____

मैं _____ पत्नी/पुत्र/पुत्री _____ निवासी _____ इस शोधकार्य "**ROLE OF ULTRASOUND IN THE DIAGNOSIS OF CARPAL TUNNEL SYNDROME**" में भाग लेने के लिए सहमत हूँ। मैं इस शोधकार्य में भाग लेने के लिए अपनी स्वेच्छा से तैयार हूँ। मैं पुष्टि करता/करती हूँ की यह स्वीकृति देने के लिए मुझे कोई आर्थिक प्रलोभन नहीं दिया गया और न ही दबाव डाला गया है। मुझे इस शोधकार्य का उद्देश्य स्पष्ट कर दिया गया है और मुझे यह विश्वास है की यह विज्ञान और मानवता के लाभ के लिए है। मुझे इस शोधकार्य में होने वाले जोखिम के बारे में समझा दिया गया है और मेरी समझ में यह जोखिम बहुत मामुली है।

मैं इस शोधकार्य में भाग लेने के सम्बन्ध में किसी भी समय अपनी अस्वीकृति व्यक्त कर सकता/सकती हूँ और मेरे अस्वीकृति व्यक्त करने का मेरे इलाज पर कोई प्रभाव नहीं पड़ेगा।

_____
गवाह के हस्ताक्षर
नाम:

_____
रोगी के हस्ताक्षर/अंगूठे का निशान
नाम:

_____
अन्वेषक के हस्ताक्षर

_____
विद्यार्थी के हस्ताक्षर

ਮਰੀਜ਼ਰਜ਼ਾਮੰਦੀਫਾਰਮ

ਮਿਤੀ_____

ਮੈ_____ਪਤਨੀ/ਪੁੱਤਰ/ਪੁੱਤਰੀ_____

ਵਾਸੀ _____

"ROLE OF HIGH FREQUENCY ULTRASOUND IN THE DIAGNOSIS OF CARPAL TUNNEL SYNDROME" ਤੇ ਚਲ ਰਹੀ ਖੋਜ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਰਜ਼ਾਮੰਦ ਹਾਂ। ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਮੈ ਆਪਣੀ ਮਰਜ਼ੀ ਨਾਲ ਤਿਆਰ ਹਾਂ। ਮੈ ਇਹ ਦਸਣਾ ਚਾਹੁੰਦਾ ਹਾਂ/ ਚਾਹੁੰਦੀ ਹਾਂ ਕੇ ਇਹ ਰਜ਼ਾਮੰਦੀ ਦੇਣ ਵਾਸਤੇ ਮੈਨੂ ਕਿਸੇ ਵੀ ਤਰਾਂ ਦਾ ਲੋਭ-ਲਾਲਚ ਨਹੀ ਦਿੱਤਾ ਗਿਆ ਅਤੇ ਨਾ ਹੀ ਕੋਈ ਦਬਾ ਪਾਇਆ ਗਿਆ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਦਾ ਮਨੋਰਥ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਭਰੋਸਾ ਦਵਾਇਆ ਗਿਆ ਹੈ ਕੇ ਇਹ ਖੋਜ ਵਿਗਿਆਨ ਅਤੇ ਮਾਨਵਤਾ ਦੀ ਭਲਾਈ ਲਈ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਵਿਚ ਹੋਣ ਵਾਲੇ ਖਤਰੇ ਬਾਰੇ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਯਕੀਨ ਹੈ ਕੇ ਇਹ ਖਤਰਾ ਬਹੁਤ ਮਾਮੂਲੀ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਦਾ ਢੰਗ – ਤਰੀਕਾ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ।

ਮੈ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਬਾਰੇ ਆਪਣੀ ਰਜ਼ਾਮੰਦੀ ਕਿਸੇ ਵੀ ਸਮੇ ਵਾਪਸ ਲੈ ਸਕਦਾ ਹਾਂ/ ਸਕਦੀ ਹਾਂ ਅਤੇ ਮੇਰੀ ਰਜ਼ਾਮੰਦੀ ਵਾਪਸ ਲੈਣ ਦਾ ਮੇਰੇ ਇਲਾਜ ਤੇ ਕੋਈ ਅਸਰ ਨਹੀ ਹੋਵੇਗਾ।

_____ _____

ਗਵਾਹ ਦੇ ਹਸਤਾਖਰ ਮਰੀਜ਼ ਦੇ ਹਸਤਾਖਰ

ਮਿਤੀ_____ ਮਿਤੀ_____

ਪਤਾ _____ ਪਤਾ _____

_____

ਨਿਰੀਖਕ ਦੇ ਹਸਤਾਖਰ

_____

ਸਿਖਿਆਰਥੀਦੇਹਸਤਾਖਰ

PATIENT PROFORMA

Bio-Data

Name	Age
Sex	Husband/Father's Name
MRD no.	OPD/IPD
Address	Phone No
Occupation	Consultant
Height	Weight
BMI	

Chief complaints-

History of present illness(in brief)-

Past history-

Any history of-

1. Trauma to hand
2. Diabetes mellitus
3. Thyroid disease or any other endocrine disorders
4. H/o Connective tissue disorder/RA
5. Similiar symptoms in past or other members of family

_____ _____

Signature of Candidate **Signature of Supervisor**

Clinical examination-

General physical examination (in brief)

Clinical examination of Hand-Movements

-Sensation

-Grip

Clinical tests

1. Tinel's sign test

2. Phalen's test

Investigations(if done)-

Random Blood sugar Fasting blood Sugar

HbA1c

Thyroid Function Tests-

T3

T4

TSH

Any other investigations(if done)

_____ _____

Signature of Candidate **Signature of Supervisor**

Ultrasound findings-

1. Nerve Hypoechogenicity / Swelling-

2. Cross sectional area of nerve at wrist-

3. Flattening of the nerve-

4. Bowing of flexor retinaculum-

5. Any anatomical variation-

Findings of Nerve conduction studies-

Motor Nerve conduction studies

Median Nerve (Over Abductor pollicis brevis)	**Distal Latency(ms)**	**CMAP Amplitude (mV)**	**NCV (m/s)**
Right			
Left			

Ulnar Nerve	**Distal Latency(ms)**	**CMAP Amplitude (mV)**	**NCV (m/s)**
Right			
Left			

_____ _____

Signature of Candidate **Signature of Supervisor**

Sensory Nerve conduction studies

Median Nerve	Distal Latency(ms)	CMAP Amplitude (μV)	NCV (m/s)
Right			
Left			

Ulnar Nerve	Distal Latency(ms)	CMAP Amplitude (μV)	NCV (m/s)
Right			
Left			

Impression of NCS findings-

Conclusion-

_____ _____

Signature of Candidate **Signature of Supervisor**